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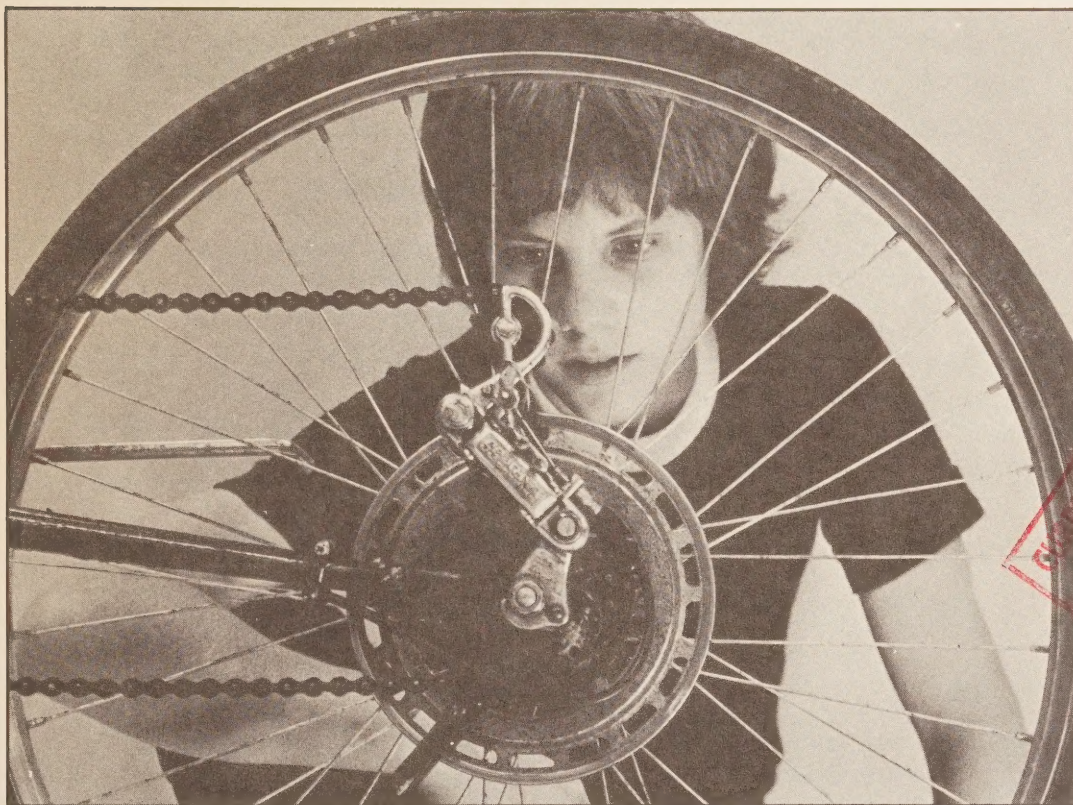
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Minister of Education
The Honourable Bette Stephenson, M.D.

Curriculum Guideline for the
Intermediate Division

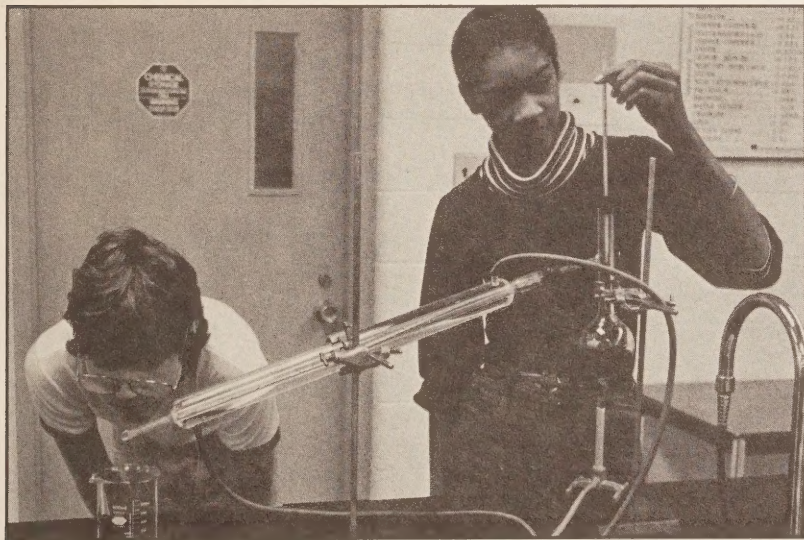
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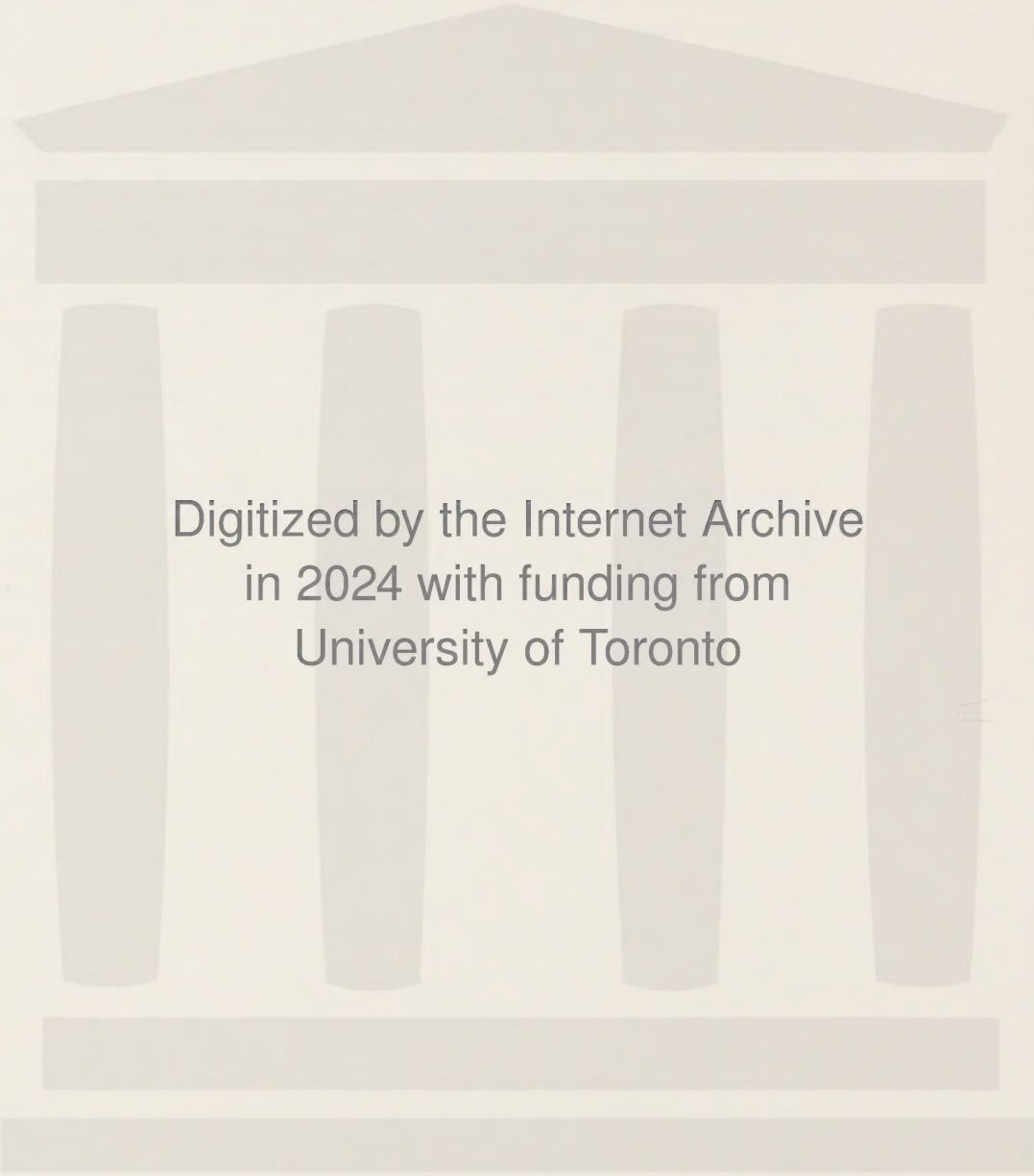
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Preface

This guideline outlines Ministry of Education policy for the development of science courses in the Intermediate Division in Ontario schools and provides suggestions and other support materials for science teachers in the province. Part A: Curriculum Policy states the requirements of the Ministry of Education regarding science in the Intermediate Division. These statements are, by their very nature, prescriptive and binding on all concerned. Part B: Implementation Objectives is to be taken as strongly recommended, offering alternatives related to the setting of expectations. Since the formulation of objectives should be a matter of local concern based on Ministry policy, Part B will assist school boards in determining those components that are a part of the science program and its implementation. The advice given in Part B is taken from several perspectives implying, therefore, that there are different ways of looking at objectives and strategies for achieving such expectations. Part C: Teaching Suggestions contains a collection of practical ideas for teachers. This material is not in the category of formal policy, but is presented as a resource that should be considered as curriculum suggestions for science teachers in the implementation of policy. Part D consists of three appendices that deal with certain topics in greater depth.

A list of resource materials will be issued in a separate document.

This document supersedes the guideline *Science, Intermediate Division, 1972*, and the part of the guideline, *Technical Subjects RP. 27, Intermediate and Senior Divisions, 1963*, that deals with science in Grades 9 and 10.



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Part A: Curriculum Policy



Introduction

The science program based on this document is to be one that involves setting appropriate expectations, selecting material and organizing experiences to meet such goals, implementing courses that will achieve these objectives, and evaluating the program to ensure that growth has taken place in the students consistent with the expected objectives. This document, then, outlines some of the bases for building a science program for students in their adolescent years.

The Intermediate Division science program is to emphasize breadth rather than depth, although an in-depth treatment may be given here and there where conditions permit. Students in the Intermediate Division should be exposed to a broad perspective involving a variety of units of study in biology, chemistry, physics, and where appropriate, earth and space science as well. With this background, students can then choose, if they wish, to take further courses in the Senior Division, where various branches of science can be studied at greater depth.

Science courses in the Intermediate Division may be “integrated courses” where the life and physical sciences are taught jointly within each course; there may be “discipline courses” where some courses should be entirely biological and others entirely physical; or there may be a mixture of integrated and discipline courses over the four years.

It is expected that the local design of all Intermediate Division science programs shall incorporate such components as:

- aims and objectives;
- levels of difficulty to accommodate the needs of various groups of students;
- desirable attitudes and values that might be encouraged;
- manipulative skills and intellectual processes;
- scientific content;
- pedagogical techniques and resources;
- related policies as outlined on pages 23-4;
- evaluation of student achievement;
- evaluation of the program.

Aims

The science curriculum for the Intermediate Division will provide opportunities for students:

- to gain a breadth of experience in the fundamentals of science;
- to understand scientific facts, definitions, concepts, principles, laws, models, and theories;
- to consider interrelationships between humans and their biological and physical environments;
- to improve their techniques of inquiry and laboratory investigation with a particular emphasis on safety;
- to develop the ability to distinguish fact from opinion, to identify problems, to develop hypotheses;
- to design methods of experimentation and testing, to manipulate and control variables;
- to collect and process data, to evaluate and interpret evidence, to form valid conclusions;

- to present and assess explanations, to propose theories and models, to formulate generalizations, and to understand conceptual schemes;
- to develop clear and accurate communication skills (written, oral, and visual) and to use these skills in recording information, in listening, in reporting, in demonstrating, and in expressing ideas;
- to increase competency in observing, identifying, classifying, inferring, comparing, measuring, tabulating, graphing, illustrating, and applying;
- to learn to solve qualitative and quantitative problems in a clear and precise manner;
- to develop attitudes of curiosity and interest in natural phenomena, of care and honesty in investigation, of enjoyment and satisfaction in learning, and of co-operation and openness in human relationships;
- to appreciate the contributions made by various men and women to the scientific enterprise;
- to relate science to career opportunities in technology, industry, commerce, business, medicine, engineering, education, research, and other areas in which science plays a role;
- to cultivate an active concern regarding such issues as the wise use of energy, the preservation of an unpolluted environment, the care of plants and animals, and the dignified application of science to societal problems.

Criteria for Evaluating the Science Program

The science program in the Intermediate Division should be appropriate, experiential, and developmental. These are the three major criteria to be followed in designing and evaluating the program.

An appropriate program

The science program must be appropriate to the needs and abilities of the students and must display such characteristics as continuity, relevance, diversity, and coherence. It must be structured so that the science curriculum of the Intermediate Division is a sequential part of the science continuum from the Primary and Junior divisions to the Senior Division. The study of science must be made relevant to the students' own lives, to their environment, and to other subjects in the curriculum. Courses are to be logically arranged with unifying themes or emphases wherever possible. Yet there must be a diversity of material so that students can see the broad spectrum of science, rather than a narrow, specialized band of content. By the end of the Intermediate Division, interrelationships among diverse phenomena should be coherent to the students through their understanding of major scientific principles and laws.

An experiential program

The science program must be experiential, providing students with experiences that characterize scientific endeavour, such as knowing, inquiring, and explaining. Knowledge will be gained by examining natural phenomena and by processing information. Empirical and theoretical methods of inquiry will allow students to experiment and discover. Students must be given opportunities to explain information, to test explanations, and to make further revisions based on additional evidence.

A developmental program

The science program must be developmental. It must allow students to increase their knowledge and understanding of the language of science with its concepts, principles, schemes, theories, models, and applications.

It must allow them to continue to develop a variety of science-related skills and to have opportunities to use well-tried intellectual processes as a basis for the learning and doing of science. Both qualitative and quantitative problem-solving are important features of the program. Students must be given experiences that will foster and encourage the development of positive attitudes and values towards scientific issues of personal, social, and environmental concern. A sample elaboration of these criteria can be found in Part B, pages 28-35.

* * * *

To stress the need to ensure that the science program shall include more than a predominantly content-oriented emphasis, some lists of examples of other aspects that are to be incorporated in the program are shown below. Ministry policy requires the inclusion of such components in the science program of the Intermediate Division.

Scientific skills

There is to be the continuing development of scientific skills – manipulative and graphic techniques – such as the ability to:

- measure quantities in metric units;
- measure microscopic dimensions;
- tabulate data and develop graphs;
- draw scientific diagrams;
- utilize techniques related to microscopy;
- perform simple dissections;
- safely operate heat sources, electrical apparatus, mechanical devices, and laboratory glassware;
- perform experiments in biology, chemistry, and physics;
- handle living plants and animals with care;
- use devices wisely in order to reduce energy wastage.

Processes

Intellectual processes such as the following are to play a role in the learning and doing of science:

- identifying problems;
- developing hypotheses;
- designing experiments and methods of testing;
- identifying, manipulating, and controlling variables;
- organizing and processing data;
- interpreting and explaining findings;
- proposing theories and forming models;
- formulating generalizations;
- inferring relationships;
- evaluating conclusions;
- substantiating hypotheses;
- understanding conceptual schemes.

Solutions to problems

Finding solutions to problems in a variety of forms is to be a part of the program, emphasizing both qualitative and quantitative methods through such activities as the following:

- reading, writing, and reporting;
- observing and describing;
- listening, feeling, tasting, and smelling;
- identifying and classifying;
- comparing and placing or listing in order;
- designing and constructing;

- finding examples and applications;
- formulating sensible questions;
- measuring many different kinds of quantities;
- estimating magnitudes within a reasonable range;
- understanding scientific and exponential notation;
- approximating and rounding off, and applying the correct number of significant digits;
- performing mathematical operations (the use of hand calculators can be encouraged);
- solving appropriate equations;
- using ratio and proportion, decimals, and percentages;
- deriving information from tables of data and from graphs;
- using mathematical, chemical, and metric notation in accordance with accepted conventions.

Attitudes

Positive attitudes towards scientific endeavour, such as the following, are to be encouraged:

- curiosity towards the unknown;
- honesty in investigation;
- willingness to be questioned;
- risk-taking in developing a new approach;
- desire for accurate work, double-checking, and high-calibre reporting;
- confidence in work well done;
- satisfaction in inquiry;
- consideration towards others;
- willingness to share and assist;
- respect for and interest in our scientific heritage;
- concern for the wise use of energy and resources;
- desire to use one's scientific interests in the advancement of human welfare.

Courses of Study

Courses for Grades 7 and 8

Students in Grades 7 and 8 will take two courses in science, one in Grade 7 and one in Grade 8, which will be made up of at least twelve units of study over the two years. The twelve units are to consist of the six core units (Units E1 to E6) and at least six additional units to be selected from the optional units (Units E7 to E24). The units are listed on page 12 and are identified by the letter E. *A unit consists of its mandatory topics along with any of the remaining optional topics that are considered desirable.* (See "Topics of Study" on pages 12-17.) It is expected that the time allotted for the courses will be evenly divided between core and optional units. In determining the amount of content, it has been assumed, for purposes of this guideline, that each course in Grades 7 and 8 will consist of about seventy hours of scheduled time, that is, about three periods per week. More time may be allotted.

If considered desirable and feasible, more than two courses based on this guideline may be offered for a Grade 7 and 8 program, provided each student selects no more than two courses that include a total of at least twelve units, six of which are core. The courses may differ for different groups of students through the use of different sets of optional units. Such an arrangement might be appropriate to a large elementary school.

Courses for Grades 9
and 10

Students in Grades 9 and 10 may take up to three science courses based on this guideline. Each course shall consist of a minimum of 110 hours of scheduled time for credit purposes (roughly equivalent to five periods of forty minutes each per week). At least eight units of study are to be selected from the list shown on page 12 for each course, provided the following conditions are met.

Students who choose to take only one science course based on this guideline shall take such a course provided that it contains at least four of the core units (Units S1 to S8). A complementary course containing the remaining core units should be available to any of these students who may later decide to take a second science course.

Students who choose to take two science courses based on this guideline shall select two courses that contain a minimum of sixteen units including the eight core units (Units S1 to S8) and at least eight optional units (Units S9 to S27). There are many possible arrangements of the units of study within the different science courses. For example, all of the core units could be included in the Grade 9 course and none in the Grade 10 course. Three core units could be included in Grade 9 and the other five in Grade 10. The core units may be distributed evenly, with four in each grade. However, students who take only one course must take one that contains at least four core units.

Students may be given the opportunity to take a maximum of three science credit courses based on this guideline. This is permitted, provided that these courses include the eight core units.

Courses in
environmental science

Intermediate Division courses in environmental science, based on the guideline *Environmental Science, Intermediate and Senior Divisions, 1973*, may be substituted for or given in addition to the science courses that are derived from this guideline for Grades 9 and 10. Each course must be identified as either a science course or an environmental science course: science and environmental science cannot be combined in one course for credit purposes. If a student takes both science and environmental science, the requirements governing core units in science courses remain unchanged with respect to the policy set forth in the previous section.

Science courses for the
Intermediate Division

The following array is a summary of the Intermediate Division science program based on this document. Each small rectangle represents a unit of study. The letter E represents a Grade 7 or 8 unit and the letter S represents a Grade 9 or 10 unit. There is no restriction as to which rectangles represent core units and which represent optional units.

Grade 7 and 8 Science Program Minimal Requirements

E	E	E	E	E	E
E	E	E	E	E	E

Two science courses consisting of a total of 12 units of study: 6 core units and 6 optional.

Grade 9 and 10 Science Program Minimal Requirements

Any one of the following programs may be taken by a student.

S	S	S	S	S	S	S	S
---	---	---	---	---	---	---	---

(a) One science course*
One science course consisting of 8 units of study, of which at least 4 must be core units.

S	S	S	S	S	S	S	S
---	---	---	---	---	---	---	---

(b) Two science courses
Two science courses consisting of a total of 16 units of study: 8 core units and 8 optional.

S	S	S	S	S	S	S	S
---	---	---	---	---	---	---	---

(c) Three science courses

S	S	S	S	S	S	S	S
---	---	---	---	---	---	---	---

Three science courses consisting of a total of 24 units of study: 8 core units and 16 optional.

S	S	S	S	S	S	S	S
---	---	---	---	---	---	---	---

S	S	S	S	S	S	S	S
---	---	---	---	---	---	---	---

*Note: The credit required in science towards the Secondary School Graduation Diploma is earned upon successful completion of a course based either on this guideline (provided it contains at least four core units) or the environmental science guideline.

Courses at the general and advanced levels

This guideline applies to courses for students taking science at the general or advanced levels, where such levels apply. As students mature through the Intermediate Division, they should be encouraged to decide on their own, with some parental and staff guidance, and taking into consideration their future goals, at which level they can best perform. Undue pressure should not be brought to bear upon students with regard to future intentions concerning post-secondary science programs.

The design of courses at different levels is fairly flexible, and courses of many different arrangements are possible. For example, two biology courses may be offered in Grade 9, one at the general and one at the advanced level. Both of these would probably include the same core units – S1, S3, S4, and S7 – although treated at different levels. Each of these courses would also include four optional units selected in the best interests of the students. These optional units need not be identical in both levels. In the following year, in Grade 10, two physical science courses could be offered at the two levels. The balance of the core units – S2, S5, S6, and S8 – would be included along with four additional optional units. Again, these courses might differ considerably for the two levels.

Alternatively, a general- and an advanced-level course could be offered in Grade 9, each consisting of all eight core units (thus integrating the biological and physical sciences). There could then be several optional courses offered in Grade 10. One might be another integrated course, one a biological science course, and one a physical science course.

The choice of optional units and topics can assist in permitting appropriate differences between general- and advanced-level courses. The method of approach, the time taken per topic, the academic expectancy, the demands on student skill and performance, and the methods of evaluation must obviously differ substantially between general- and advanced-level courses.

This document is applicable to teachers of students who are enrolled in Special Education and special vocational and occupational courses, although it has not been planned primarily for them. In designing science courses for these students, teachers should follow the general intent of this guideline – to provide a grounding in the fundamentals of science, including the aims, criteria, and related policies contained herein. However, basic-level and modified-level courses should be created to meet the needs of those students for whom they are designed. Units and topics may be treated with greater flexibility than for general- and advanced-level courses. Thus, decisions on the number of core and optional units or mandatory and optional topics in this special area shall be the responsibility of each school board. Science courses based on this guideline, but designed as basic- or modified-level courses, qualify as credit courses towards the Secondary School Graduation Diploma.

Units of Study

Local decisions

Within the policy structure outlined in the previous sections, each school board is responsible for developing its own science curriculum. Thus, for example, a school board, in consultation with its teachers, might decide to select a number of optional units as mandatory units for its schools, thereby creating a local core in addition to the provincial core outlined already. In matters of this kind, the school board must clearly specify who is responsible for making local decisions – for example: the administration, a local science committee, the science co-ordinator, families of schools, individual schools, or individual science teachers.

Locally designed units

Within the optional units listed on page 12, seven (three for Grades 7 and 8 and four for Grades 9 and 10) are designated as “locally designed units”. These are provided to permit school boards the freedom to develop, adopt, or adapt from other sources a sizeable portion of their science program to suit local needs. Locally designed units are to be equivalent in scope, content, and time allotment to other units.

School boards may create more than seven locally designed units from which different groups of students may make a variety of selections. For example, if biological science is offered in Grade 9 and physical science in Grade 10, there could be two different courses in each year, one at the general level and another at the advanced level. Each course could have the same four core units but different choices of optional and locally designed units. The number of locally designed units would be shared between the two years so that the sum of such units taken by any student in the two successive courses does not exceed four. Thus, there could be up to four locally designed units at the general level and up to four at the advanced level with different content material in the two sets of units.

In the same way, if the eight core units are taught (at different levels of difficulty) in Grade 9, several different courses could be offered in Grade 10. If, for example, three such Grade 10 courses are offered (in integrated science, biological science, and physical science), the locally designed units may number up to four in each of the three courses with all such units being different from one another. Thus, although no one student would take more than the prescribed four locally designed units, the school would in fact be offering twelve such units.

If three courses are taken by a student in the program for Grades 9 and 10, the three courses may contain up to eight locally designed units. For example, two courses may contain the eight core units and eight optional units, four of which may be locally designed. The third course would then contain only optional units, but no more than four new locally designed units.

Units on the “Wise Use of Energy”

Two optional units on the “Wise Use of Energy” (E21 for Grades 7 and 8 and S23 for Grades 9 and 10) deserve special emphasis. It is a matter of national importance today to persuade Canadians to reduce their consumption of energy. The attitudes of adolescents are still in the formative stage in the Intermediate Division, and it is important for them to deliberately consider their present energy-use habits and to develop practices that are conducive to maintaining a clean and healthy environment. Students must learn to appreciate their personal influence on the flow-rates through such energy systems as transportation, food, agriculture, manufactured goods, communications, waste, space heating, water, and electricity.

School boards must give serious consideration to the inclusion of one or more units on the “Wise Use of Energy” in the Intermediate Division science program. There are no topics listed for such units; therefore, it is the responsibility of the school board to develop them. These topics must be carefully designed in conjunction with related studies in other subject areas. Units on the Wise Use of Energy are to be equivalent in scope, content, and time allotment to other units. For assistance in such planning, school boards are advised to refer to the resource guide entitled *Energy in Society, 1978*, prepared by the Ministry of Education. If it is found desirable to expand on these units, one or more locally designed units may be created for this purpose.

Locally designed units and units on the “Wise Use of Energy” provide a wide scope for local curriculum development. It is recommended that outlines of all such units be prepared. A copy of each outline should be kept on file in the office of the school board.

Arrangement of units

Once the units for a given course have been selected, they may be taught in any order desired, but each unit must be completed within a single science course. Within either the program for Grades 7 and 8 or the program for Grades 9 and 10, all of the core units may be placed in one year with the optional units in the other, or the core and optional units may be distributed between the two years at the discretion of the local board. The distribution of core units for students who take only one course in Grades 9 and 10 is subject to the restriction outlined on page 8.

List of units of study

The following are the units of study prescribed for science in the Intermediate Division. The units are listed alphabetically in each category.

Units for Grades 7 and 8	Units for Grades 9 and 10
Core Units	Core Units
E1 Characteristics of Living Things	S1 Cells and Their Processes
E2 Classification of Living Things	S2 Chemical Change
E3 Force and Energy	S3 Functioning Animals
E4 Interdependence of Living Things	S4 Green Plants
E5 Measurement	S5 Heat
E6 Properties of Matter	S6 Measurement
	S7 Populations and Communities
	S8 Structure of Matter
Optional Units	Optional Units
E7 Adaptation and Behaviour	S9 Consumer Chemistry
E8 Astronomy	S10 Continuity
E9 Forestry Resources	S11 Electricity and Magnetism
E10 Heat and Temperature	S12 Environmental Chemistry
E11 Life Cycles	S13 Fungi and Simple Plants
E12 Light	S14 Geometric Optics
E13 Magnetism and Electricity	S15 Human Interaction With the Biosphere
E14 Mining Resources	S16 Machines
E15 Plants	S17 Mechanics
E16 Rocks and Minerals	S18 Separation of Substances
E17 Simple Machines	S19 Solutions
E18 Solutions	S20 Terrestrial and Aquatic Environments
E19 Water	S21 Vibrations and Waves
E20 Weather	S22 Viruses, Monerans, and Protists
E21 Wise Use of Energy	S23 Wise Use of Energy
E22 Locally designed unit	S24 Locally designed unit
E23 Locally designed unit	S25 Locally designed unit
E24 Locally designed unit	S26 Locally designed unit
	S27 Locally designed unit

Mandatory and optional topics

Topics of Study

Each unit, whether core or optional, contains a set of topics, as outlined on pages 13-22. Some topics are listed as mandatory; the rest are optional. *Each unit will consist of its mandatory topics along with any of the remaining optional topics that are considered desirable.* Optional topics may be included with, omitted, or replaced by other topics that are selected locally.

To some extent, the choice of optional topics will be governed by the time available. The length of time spent on a unit in Grades 7 and 8 will average about five weeks, since a minimum of six units are to be taught in each year. The length of time for a unit in Grades 9 and 10 will be about one month, since each course consists of at least eight units.

Arrangements of topics

Once the units for a given course have been selected, the corresponding topics may be rearranged in any order desired. Topics may be taken from more than one unit and blended into a single larger unit of study under an entirely new heading. For example, the three units on the characteristics,

classification, and interdependence of living things (Units E1, E2, and E4) may be grouped together to form a larger single unit on living things, with the various topics realigned in a new order.

The topics of one unit may also be separated and inserted into other units at appropriate places. For example, the unit on measurement (E5) can be arranged so that each topic is taught with the specific investigation of another unit that requires that particular concept or metric unit of measure.

Courses need not be taught unit by unit as listed in this guideline. As long as the mandatory topics within the required number of units are arranged to form a suitable program, the policy governing the inclusion of content is considered to have been implemented.

One reason for permitting a local alignment of topics is to enable school boards to continue, to some extent, to use approved textbooks presently listed in *Circular 14*. Although such texts may not be entirely compatible with the units and topics listed in this guideline, locally designed units and topics can be used to bridge the gap between this new curriculum guideline and the existing texts. New texts will undoubtedly be produced to conform more closely with the intent of this guideline.

List of topics within
each unit

The following lists outline the topics within each unit of study. Topics that are marked with an asterisk are a mandatory part of the units to which they relate. The remaining topics within a unit are suggested for consideration, provided time and circumstances permit. It is the policy of the Ministry of Education that the following units and their topics, selected as directed, comprise the science program of the Intermediate Division.

Topics for Grades 7 and 8

* mandatory topics

Unit E1 **Characteristics of Living Things**

- E1.1 Variety of organisms
- E1.2 *Movement and locomotion
- E1.3 *Growth
- E1.4 *Reproduction
- E1.5 *Metabolism
- E1.6 Cellular basis of life
- E1.7 *Irritability
- E1.8 *Adaptation

Unit E2 **Classification of Living Things**

- E2.1 Need for classification
- E2.2 Classification systems
- E2.3 *Informal biological classification
- E2.4 *Formal biological classification
- E2.5 *Classification of plant specimens
- E2.6 †Fungi
- E2.7 †Mosses
- E2.8 †Ferns
- E2.9 †Seed producers
- E2.10 *Invertebrates
- E2.11 *Vertebrates

† At least one of the topics marked with a dagger is mandatory.

<i>Unit E3</i>	Force and Energy
E3.1	Examples of forces
E3.2	*Measurement of forces
E3.3	*Force of gravity
E3.4	*Force of gravity and its relationship to mass
E3.5	*Work
E3.6	*Measurement of work
E3.7	*Energy
E3.8	Potential energy
E3.9	Kinetic energy
E3.10	*Forms of energy
E3.11	*Energy conversion
E3.12	Wise use of energy
<i>Unit E4</i>	Interdependence of Living Things
E4.1	*Natural communities
E4.2	*Concept of an ecosystem
E4.3	*Types of communities
E4.4	*Producers, consumers, and food chains
E4.5	Photosynthesis and respiration
E4.6	Biological change
E4.7	*Disturbance of balance
E4.8	*Human influence
<i>Unit E5</i>	Measurement
E5.1	The need for quantitative description
E5.2	Physical quantities and their units
E5.3	*Linear units
E5.4	Averaging
E5.5	Rounding
E5.6	*Area units
E5.7	*Volume units
E5.8	*Mass units
E5.9	*Time units
E5.10	*Temperature units
E5.11	Rate of change
<i>Unit E6</i>	Properties of Matter
E6.1	Description of an object
E6.2	Description of a single substance
E6.3	*Properties, functions, and inferences
E6.4	*Qualitative and quantitative properties
E6.5	*Biological, chemical, and physical properties
E6.6	*Diversity of physical properties
E6.7	*Solid, liquid, and gas
E6.8	*Matter
E6.9	Non-matter
E6.10	Applications of matter based on properties
<i>Unit E7</i>	Adaptation and Behaviour
E7.1	Inherited behaviour
E7.2	*Tropisms and taxes
E7.3	*Learned behaviour
E7.4	*Protective mechanisms
E7.5	*Body language

<i>Unit E8</i>	Astronomy
E8.1	Historical development
E8.2	Orbital motion
E8.3	*The earth
E8.4	*The moon
E8.5	*The planets
E8.6	*The sun
E8.7	*The stars
E8.8	Other celestial bodies
E8.9	Astronomical instruments
<i>Unit E9</i>	Forestry Resources
E9.1	*Northern boreal forest
E9.2	*Great Lakes - St. Lawrence regional forest
E9.3	*Forest products
E9.4	Forest land use
E9.5	Forests, soil, and water
<i>Unit E10</i>	Heat and Temperature
E10.1	Sources of heat
E10.2	*Expansion of metals
E10.3	*Expansion of water
E10.4	*Expansion of air
E10.5	*Meaning of temperature
E10.6	*Conduction
E10.7	*Convection
E10.8	Radiation
E10.9	*Melting of ice
E10.10	Boiling of water
E10.11	Kinetic molecular theory
<i>Unit E11</i>	Life Cycles
E11.1	*Comparison of asexual and sexual reproduction
E11.2	*Examples of asexual reproduction
E11.3	*Examples of sexual reproduction
E11.4	†Life cycle of a fern
E11.5	†Life cycle of a seed-bearing plant
E11.6	†Life cycle of an earthworm
E11.7	†Life cycle of insects
E11.8	†Life cycle of a frog
† At least two of the topics marked with a dagger are mandatory.	
<i>Unit E12</i>	Light
E12.1	*Rectilinear propagation of light
E12.2	*Transparent, translucent, and opaque materials
E12.3	*Reflection
E12.4	*Refraction
E12.5	Lenses
E12.6	The spectrum

<i>Unit E13</i>	Magnetism and Electricity
E13.1	Magnetic substances
E13.2	*Magnetic poles
E13.3	*Magnetic forces
E13.4	Magnetic fields
E13.5	Production of magnets
E13.6	The earth as a magnet
E13.7	*Electric charges
E13.8	*Electric attraction and repulsion
E13.9	*Electric current
E13.10	Electric cell
E13.11	*Electric circuit
E13.12	Series and parallel components
E13.13	*Electromagnets
<i>Unit E14</i>	Mining Resources
E14.1	*Why mine?
E14.2	How to find an ore body
E14.3	How to mine an ore body
E14.4	*Mineral processing
E14.5	*Smelting, converting, and refining
<i>Unit E15</i>	Plants
E15.1	Classification of plants
E15.2	*Plant structures
E15.3	*Flowers and fruits
E15.4	*Seeds
E15.5	Plant growth
E15.6	Plant projects
<i>Unit E16</i>	Rocks and Minerals
E16.1	*Differences between rocks and minerals
E16.2	*Rock classification
E16.3	*Rock formations
E16.4	Erosion and weathering
E16.5	*Energy fuels
E16.6	Fossil study
E16.7	Mineral-identification tests
E16.8	Crystal formation
E16.9	*Metallic minerals
E16.10	*Non-metallic minerals
E16.11	Gem minerals
<i>Unit E17</i>	Simple Machines
E17.1	*Concept of a machine
E17.2	*Our use of machines
E17.3	Simple and complex machines
E17.4	*Principle of work
E17.5	*Efficiency
E17.6	Mechanical advantage
E17.7	Concept of friction
E17.8	Experimental study of friction
E17.9	Experimental study of levers
E17.10	*Machines in our lives

<i>Unit E18</i>	Solutions
E18.1	*Characteristics of a solution
E18.2	*Saturated and unsaturated solutions
E18.3	*Supersaturated solutions
E18.4	*Testing for degree of saturation
E18.5	Crystals
E18.6	*Rate of solution
E18.7	Exothermic and endothermic reactions
E18.8	*Water, the “universal solvent”
<i>Unit E19</i>	Water
E19.1	*The water cycle
E19.2	*The physics of water
E19.3	The chemistry of water
E19.4	*Water treatment
E19.5	*Water and living things
E19.6	Water as a land-changer
E19.7	Water in weather
E19.8	*Conservation of water
<i>Unit E20</i>	Weather
E20.1	Nature of the atmosphere
E20.2	*Physics of air
E20.3	*Water in the atmosphere
E20.4	*Characteristics of precipitation
E20.5	Measuring and recording atmospheric conditions
E20.6	Clouds
E20.7	Weather forecasting
E20.8	Lightning
E20.9	Air pollution and weather
<i>Unit E21</i>	Wise Use of Energy
<i>Unit E22</i>	Locally designed unit
<i>Unit E23</i>	Locally designed unit
<i>Unit E24</i>	Locally designed unit

Topics for Grades 9 and 10

* mandatory topics

Unit S1 **Cells and Their Processes**

- S1.1 *Cell discovery; microscope
- S1.2 Cell theory
- S1.3 *Cell structure
- S1.4 *Cell physiology
- S1.5 *Mitosis (reproduction)
- S1.6 Cell differentiation
- S1.7 *Cell organization
- S1.8 *Diffusion and osmosis

Unit S2 **Chemical Change**

- S2.1 *Chemical change
- S2.2 *Word equations
- S2.3 Chemical equations
- S2.4 Conservation of mass
- S2.5 Balancing chemical equations
- S2.6 Conservation of mass and the open system
- S2.7 Qualitative tests
- S2.8 *Studies of chemical change

Unit S3 **Functioning Animals**

- S3.1 Metabolism
- S3.2 *Breathing systems
- S3.3 *Gas exchange and the role of oxygen
- S3.4 Breathing and health
- S3.5 *Digestive system
- S3.6 *Nutrition
- S3.7 Food and energy

Unit S4 **Green Plants**

- S4.1 Plant community
- S4.2 *Role of green plants
- S4.3 *Photosynthesis
- S4.4 Equation for photosynthesis
- S4.5 *Absorption
- S4.6 Diffusion and osmosis
- S4.7 Conduction
- S4.8 *The leaf
- S4.9 Ecological role of plants
- S4.10 *Humans and plants

Unit S5 **Heat**

- S5.1 Thermal expansion (review)
- S5.2 Heat transfer (review)
- S5.3 Changes of state
- S5.4 Early theories of heat
- S5.5 Particle nature of matter

S5.6	*Quantity of heat
S5.7	*The joule
S5.8	*Specific heat capacity
S5.9	Method of mixtures with water
S5.10	Specific heat capacity of metals
S5.11	Heat of fusion of ice
S5.12	Heat of vaporization of water

Unit S6 **Measurement**

S6.1	*Length
S6.2	*Speed
S6.3	Area
S6.4	*Volume
S6.5	Length, area, and volume
S6.6	*Mass
S6.7	Conservation of mass
S6.8	*Mass and volume
S6.9	Concept of density
S6.10	*Measurement of density
S6.11	Density problems
S6.12	Applications of density

Unit S7 **Populations and Communities**

S7.1	*The biosphere
S7.2	Biomes
S7.3	*Ecosystems
S7.4	*Populations and communities
S7.5	*Producers, consumers, and decomposers
S7.6	*Carnivores, herbivores, and decomposers
S7.7	Mutualism and parasitism
S7.8	*Predation
S7.9	Pyramids of numbers, biomass
S7.10	Cycling of matter
S7.11	Succession

Unit S8 **Structure of Matter**

S8.1	*Some processes of science
S8.2	*The particle theory
S8.3	*The atomic theory
S8.4	Ions and conductivity
S8.5	*The elements
S8.6	Classification
S8.7	The periodic table
S8.8	*Elements and compounds

Unit S9 **Consumer Chemistry**

The following is a set of sample topics for this unit.

S9.1	*Soap and a related problem
S9.2	*The best cleanser? Developing a hypothesis
S9.3	*Designing an experiment on cleansing
S9.4	*Data on soap as a cleanser
S9.5	*Interpreting the data on soap
S9.6	*Evaluating the “cleanser hypothesis”
S9.7	Generalizations regarding the cleanser
S9.8	Explaining the soap problem

<i>Unit S10</i>	Continuity
S10.1	Reproduction in plants and animals
S10.2	*The need for meiosis
S10.3	*DNA and the genetic code
S10.4	Embryology
S10.5	Human reproductive system
S10.6	*Human genetics
S10.7	*Mendelian genetics
S10.8	*Chromosome theory
<i>Unit S11</i>	Electricity and Magnetism
S11.1	Electrostatics
S11.2	*Induction
S11.3	Shielding and discharging
S11.4	Electrochemical cells
S11.5	Electric units
S11.6	*Electric energy
S11.7	*Electric circuits
S11.8	*Magnetism
S11.9	*Electromagnetism
S11.10	Electric energy conversions
<i>Unit S12</i>	Environmental Chemistry
S12.1	*The energy crisis
S12.2	Future energy sources
S12.3	*Air pollution
S12.4	*Water pollution
<i>Unit S13</i>	Fungi and Simple Plants
S13.1	*Characteristics of fungi
S13.2	*Bread mould
S13.3	Yeast
S13.4	Mushrooms
S13.5	Parasitic fungi
S13.6	*Lichens
S13.7	*Complex algae
S13.8	*Mosses
S13.9	*Ferns
<i>Unit S14</i>	Geometric Optics
S14.1	Sources of light
S14.2	Transmission of light
S14.3	Speed of light
S14.4	*Plane reflection
S14.5	*Curved mirrors
S14.6	*Refraction
S14.7	Lenses
S14.8	*Dispersion and colour

<i>Unit S15</i>	Human Interaction With the Biosphere
S15.1	*The biosphere
S15.2	*Human characteristics
S15.3	Ecology of early and modern humans
S15.4	*Population growth
S15.5	*Values and attitudes
<i>Unit S16</i>	Machines
S16.1	*Review of machines
S16.2	†Experimental study of a pulley system
S16.3	†Experimental investigations of a machine
S16.4	†Forms of energy in machines
S16.5	†Electric project
S16.6	†Thermal efficiency
S16.7	†The operation of a machine
S16.8	†Machine problems
† Four of the topics marked with a dagger are mandatory.	
<i>Unit S17</i>	Mechanics
S17.1	*Force
S17.2	*Gravity-mass ratio
S17.3	Friction
S17.4	Coefficient of friction
S17.5	*Balanced forces
S17.6	Unbalanced forces
S17.7	Moment of force, torque
S17.8	*Work
S17.9	*Power
S17.10	Energy
S17.11	*Pressure
<i>Unit S18</i>	Separation of Substances
S18.1	*Direct filtration
S18.2	*Sedimentation
S18.3	*Floc formation
S18.4	*Simple distillation
S18.5	*Fractional distillation
S18.6	Fractional crystallization
S18.7	Paper chromatography
<i>Unit S19</i>	Solutions
S19.1	*Solutions and mixtures
S19.2	*Molecular explanation of dissolving
S19.3	*Concentration
S19.4	*Classes of solutions
S19.5	*Solubility
S19.6	*Volume change on mixing
S19.7	Solubility of gases in water
S19.8	Problems in solubility
S19.9	The effect of solutes on fixed points
S19.10	Solvents

<i>Unit S20</i>	Terrestrial and Aquatic Environments
S20.1	*Study of a local environment
S20.2	*Measurement of the abiotic environment
S20.3	*Temperature, rainfall, and biomes
S20.4	Major biomes
S20.5	*Measurement of biotic populations
S20.6	*Collecting of biotic specimens
S20.7	Comparison of populations
S20.8	Field experiments
S20.9	Pond and ocean ecology
<i>Unit S21</i>	Vibrations and Waves
S21.1	Sounds we hear
S21.2	*Vibrations: qualitative aspects
S21.3	*Vibrations: quantitative aspects
S21.4	Pendulums
S21.5	*Waves
S21.6	Speed of a wave
S21.7	*Transmission of sound
S21.8	Measurement of the speed of sound
S21.9	Some properties of sound waves
S21.10	*Characteristics of sounds
S21.11	Applications of sound
<i>Unit S22</i>	Viruses, Monerans, and Protists
S22.1	*Viruses
S22.2	*Monerans
S22.3	Cyanophytes
S22.4	*Structure and action of bacteria
S22.5	*Importance of bacteria
S22.6	Bacteria in the laboratory
S22.7	*Microbes and disease
S22.8	*Protists
<i>Unit S23</i>	Wise Use of Energy
<i>Unit S24</i>	Locally designed unit
<i>Unit S25</i>	Locally designed unit
<i>Unit S26</i>	Locally designed unit
<i>Unit S27</i>	Locally designed unit

Administrative Considerations

Curriculum co-operation in the Intermediate Division

It is essential that the science courses for Grades 7 and 8 and those for Grades 9 and 10 be considered together in the selection of units and topics. The four years of the Intermediate Division must provide a continuum in the science program, and such planning comes within the jurisdiction of a school board, a family of schools, or some such local school grouping. Some units in Grades 7 and 8 are closely related to certain units in Grades 9 and 10. If close co-operation between elementary and secondary levels is not achieved, there may be an undesirable amount of overlap or serious gaps where prerequisite knowledge is overlooked. Local committees can provide an overall balanced program, not only in terms of content but also in matters related to skills, processes, and attitudes to ensure satisfactory curriculum development. It is strongly recommended that all school boards whose curriculum decisions may affect a student's future in science collaborate in the formation of science courses wherever feasible.

Courses taken in different schools

Difficulties may arise when a student moves from one school to another part way through a program. Because of the move, the student may not be able to complete all of the core or optional units. In such cases, it will be at the discretion of the principal to decide on the best course of action. When the move has resulted from extenuating circumstances beyond the control of the student, the principal may waive requirements regarding core and optional units, based on his/her judgement of the future anticipated needs of the student. However, every attempt should first be made to arrange for the student to make up any missing work that may be required for future success.

Related Policies

Use of language

It is the responsibility of all teachers to encourage the correct use of English in all oral and written communication. Science teachers should expect students to spell correctly and to use proper grammatical structures. Students should learn to write logically and precisely, whether they are using point or paragraph form.

Adoption of SI units of measure

Throughout the Intermediate Division science program, students are to use SI (metric) units of measure wherever measurement is required. Other units of measure may be mentioned in relation to SI units, but only if necessary. For example, it may be pointed out that the Calorie (equal to 1 kcal) used in diets is being replaced by the kilojoule. It may be appropriate to mention that $1 \text{ Cal} = 4.2 \text{ kJ}$, because students might come across Calories in existing textbooks and reference material. As a rule, conversion from imperial or from obsolete metric units to SI units should be avoided. Wherever possible, measurements and problems should involve only SI units (including units permitted for use with SI). Any new textbooks should use SI units of measure. See Appendix A for more details on the use of SI units.

Safety

It is expected that all science teachers will stress safety in the science room or laboratory. They must instil in their students a positive attitude towards safety. Part C contains frequent cautionary statements regarding accident prevention and safety measures. Teachers must always assume responsibility for establishing and maintaining safe laboratory procedures. A more complete discussion of this topic is contained in Appendix B.

Teachers must develop in their students a respect for living organisms. All science teachers who have plants and animals in the science room should read Appendix C.

The Animals for Research Act provides for the comfort and well-being of all vertebrate animals in elementary and secondary schools and in science fairs. Teachers are also urged to foster in students a positive attitude towards plants and animals in the environment. Unfortunately, there is an alarming increase in reported incidents of the ill-treatment of animals in the world outside the school. The influence of sympathetic teachers could foster attitudes of concern and thoughtfulness for animals everywhere.

Evaluation of Student Achievement

Evaluation of student achievement is important to teachers, to the students themselves, and to their parents. It is essential that students know their own strengths and weaknesses and that they be motivated to achieve their full potential.

Parents have the right to receive a precise and clear evaluation of the progress of their youth, including their intellectual and attitudinal development. In order to provide information on student achievement, teachers need to evaluate as many aspects of student work as possible.

Teachers can use their evaluation of students' work to understand their needs and to help them further meet the aims and objectives of the science program. This is ultimately achieved when the students have learned to evaluate their own work and attitudes. Self-evaluation and self-motivation are desirable outcomes of the curriculum.

If students are to learn to evaluate their own achievements, they need to be exposed to many different forms of evaluation. As students experience a variety of testing techniques, they will understand how a composite assessment of their achievements can be formed. One purpose for testing students is to teach them how to evaluate their own work. An array of evaluation items and techniques is presented in Part B, pages 49-56. Teachers should find this helpful in developing their own evaluation program.

Policy Implementation

Since this is a lengthy document, it is recommended that the teacher first become familiar with the policy set forth in Part A. When designing the program so that courses will incorporate not only content but also aspects such as scientific processes, learning objectives, skill development, achievement evaluation, and program assessment, the teacher should refer to Part B. The teacher should examine Part C when he/she wishes to explore a suggested treatment of a unit or topic.

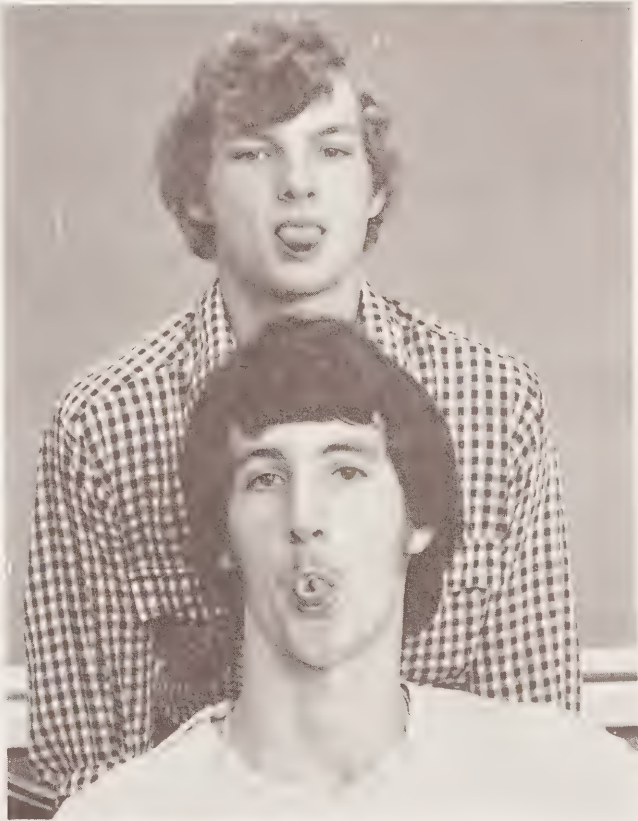
The following checklist is recommended for use when implementing the policy set forth in this guideline:

1. In consultation with elementary and secondary science teachers, determine local policy on:
 - a) whether all schools under the jurisdiction of the school board should adopt more than the 50 per cent core content outlined above;
 - b) whether all schools are to teach certain units at the same time or whether the order is to be determined by each school or group of schools.

2. Consider the importance and the advisability of creating units on the "Wise Use of Energy".
3. Examine the expanded versions of all units given in Part C in order to determine the depth of treatment or coverage suggested for each.
4. Consider the particular needs of various groups of students; the choice of optional units and topics could vary considerably for different groups.
5. Examine the criteria for developing the science program as set forth on pages 5-6, and further outlined on pages 28-35. Make sure that the units and topics that are chosen satisfy these criteria. A checklist of features, other than content, that are to be incorporated in the program could be created. This checklist would include specific skills, processes, attitudes, and values that should be developed and encouraged.
6. Answer the following questions regarding locally designed units:
 - a) Are they needed?
 - b) Should they be based largely on the need to supplement the material in a particular textbook?
 - c) Are local units already available, and if not, who will develop them, and when?
 - d) To what extent are such units to be used within the schools under the jurisdiction of the school board?
 - e) Is an individual teacher or school permitted to design and implement such a unit independently of other teachers and schools?
7. Consider the availability of textbooks and resources; these may influence the selection and order of various units. However, a single text should not necessarily be the major basis on which units are selected.
8. In consultation with representatives from both elementary and secondary schools, draw up a general list of units that are considered desirable for the Intermediate Division.
9. Assign the selected units to the various grades within the Intermediate Division and decide on the order in which they are to be arranged. Care must be taken to provide for continuity of content from one grade to another.
10. Determine whether the order of the topics within the units is to remain as presented in this guideline or be reorganized in an entirely different arrangement.
11. Select optional topics giving consideration to the different levels of difficulty for which courses are being developed.

12. Ensure that Grade 9 and 10 students
 - a) who wish to take only one science course have available to them one that contains a minimum of four core units (including the provision for completion of the core by those students who later decide to take a second course in science);
 - b) who wish to take two or three science courses are able to complete the eight core units.
13. Design alternative courses other than those at the general and advanced levels, where necessary and feasible, particularly for the program for Grades 9 and 10.
14. Give special attention to the desirability of offering courses in environmental science.
15. As the implementation of units is being planned, study all the suggestions presented in Part C. Adopt those suggestions that are appropriate and improve on those that are not.
16. Create lists of performance, behavioural, or other kinds of objectives, if desired.
17. Encourage appropriate and correct use of language as a vital part of the science program.
18. Ensure that the adoption of SI units is an integral part of the curriculum.
19. Emphasize accident prevention and safety measures wherever appropriate.
20. Be prepared to prevent the ill-treatment of living vertebrate animals in the laboratory and to encourage the humane care and treatment of plants and animals everywhere.
21. Devise and implement a variety of methods for the evaluation of students that will enable them to improve their work and to enrich their appreciation of science.
22. Design a plan for evaluating the courses within the science program.

Part B: Implementation Objectives



Introduction

In this part of the guideline, interpretive advice is offered to assist in the implementation of the curriculum policy outlined in Part A. It is strongly recommended that local boards use the material in this part of the document, at least as a starting point, for the implementation of policy.

The first section, "Evaluating the Science Program", provides one example of an elaboration of the criteria presented in Part A for evaluating the science program. This section is illustrative, but should be useful in making the criteria operational.

The second section, "Some Learning Objectives in a Science Program", illustrates the diversity of objectives that can be generated. It is offered here as one example to assist local boards in the task of generating and selecting appropriate objectives for the science program.

In a somewhat lighter vein, another approach to generating objectives is offered in the third section, "Rationale for Science: A Student Viewpoint". Learning outcomes are embodied here in a sample set of reasons for studying science.

Student evaluation is the focus of the fourth section, "Methods of Evaluating Student Achievement", which includes a variety of evaluation techniques.

The final section, "Relating Science Topics to Alternative Sets of Objectives", provides a way to think about translating current policy into program. It deals with the fact that content can be used as a vehicle for the achievement of different objectives.

Evaluating the Science Program

This section presents an illustrative elaboration of the three criteria by which Intermediate Division science programs are to be evaluated (see Part A, pages 5-6). These criteria require that the science program be appropriate, experiential, and developmental.

An Appropriate Program

The science program must be appropriate to the needs and abilities of students. It must display such characteristics as continuity, relevance, diversity, and coherence.

Continuity

Because science courses are a part of the entire educational continuum from the Primary to the Senior Division, there is a need to know where the students have been, where they are, and where they are going. Teachers should have certain expectations of students when they enter Grade 7. For example, as indicated in *The Formative Years* (Circular P1J1, 1975), students should be expected to know something about length, volume, mass, force, temperature, and related skills, processes, and attitudes. When they leave Grade 10, students should carry with them ample evidence of a rich experience and a firm grounding in the fundamentals of science.

The organization of the science program should take into account the emotional, social, and intellectual needs, abilities, and development of students. Thus, knowledge of child and adolescent development is necessary in order to answer such questions as: When are students ready to consider the kinetic molecular theory, to manipulate $D = m/V$, to handle burners safely, to use microscopes effectively, or to understand chemical equations? Is ecology appropriate for the program for Grades 7 and 8?

Relevance

Many of the students' experiences in science should be related to the environment with which they interact. These can frequently involve first-hand activities, direct observation, and the use of sound intellectual processes. For example, a local stream or river may be used as the motivation for the study of Forestry Resources (Unit E9) even though there may not be a forest in the immediate vicinity of the school. Or rather than merely assigning a reading and writing project about wasted energy, the teacher may enrich a unit on the Wise Use of Energy by having students estimate the cost of the wasted energy in their own homes.

Science should not be presented in isolation. When appropriate, an interdisciplinary approach should be used. For example, Populations and Communities (Unit S7) can include some history and geography; both Light (Unit E12) and Geometric Optics (Unit S14) can be related to mathematical transformations; experiences in Measurement (Unit E5) can involve the family studies classroom (baking a cake is one way of learning to use units of volume, temperature, and time).

Diversity

The wealth of knowledge included in a science program exhibits a wide variety of ideas and concepts. While students should be exposed to as wide a variety of material as possible, they should also come to understand concepts related to the interdependence of all things. Amoebas, lichens, pieces of sodium, pendulums, fires, bricks, radios, blood, magnets, acids, water waves, cars, elastic bands, bombs, violins, storms, and sparrows are very diverse entities; yet they all have energy and all are composed of matter.

Science is a subject in which relationships among natural phenomena are emphasized. Cause-and-effect relationships are postulated, and unifying principles are determined. For example, the action of yeast in bread or the burning of coal in a furnace have no apparent connection until the process of oxidation is studied. This tying together of topics is the way in which science explains reality. Students will derive a personal sense of satisfaction from these explanations, particularly from those that help them to understand how and why they themselves function and how they interrelate with their environment. Scientific explanations may be contrasted with the divergent interpretations of reality provided by such fields as palmistry, magic, alchemy, and astrology.

Coherence

A science course, or a reasonable portion thereof, should exhibit a unified pedagogical approach that is evident to both the teacher and the students. Students encounter a great variety of content within any science course, and such content can appear to be disjointed. For instance, biology, chemistry, and physics can occur in the same course, or electricity can follow optics with little connection between the two. A course may be unified by using a thematic approach or by teaching the content with a particular emphasis. Different emphases may be adopted in different years, or perhaps two or three emphases may be applied in a single year. An elaboration of this method is provided on pages 56-69.

The sequence of units or topics within a course should have a demonstrably logical arrangement. Once a set of units has been selected for any given course, the topics can be placed in any order desired. For example, a unit such as Measurement (Unit E5) can be split up so that each topic is taught when appropriate, that is, when each metric concept or unit of measure is first required in the course. However, within the confines of

a single course, all of the topics of such a unit should be completed so that students can grasp the concept of measurement as a system and not as independent entities. Further, units such as Force and Energy (Unit E3) and Machines (Unit E10) can be combined so that the topics are intermingled to form an integrated unit of study. Some schools will wish to place all biological topics within one year and all physical topics within another in order to ensure sequential unity within each course. Other schools will wish to mix the biological and physical topics to stress the interrelationships of science as a whole. In any event, the sequencing of topics is important and must be well planned.

An Experiential Program

The science program must be experiential, providing students with experiences that characterize scientific endeavour, such as knowing, inquiring, and explaining.

Nature of scientific knowledge

Students should realize that science is a discipline that examines natural phenomena and that information so gained can be treated in two distinct ways: it can be processed and it can be explained. Often, processing and explaining go hand in hand. For example, a great deal of information is available on the characteristics of human parents and their offspring. This information may be examined by summarizing and classifying it; it may be stored in computer systems or written up in journals; it may be listed under human genetics and left for future examination. Processing information is a part of science that students should experience first-hand. Naturally, processing should have a purpose; it should lead to further investigation and explanation.

Students should process scientific information by organizing it through reports, tables, and graphs. They should identify information as being instances of facts, rules, generalizations, principles, or laws. For example, information related to objects or substances that float or sink in water may be gathered, tabulated, graphed, and eventually summarized into *facts* (all samples of styrofoam floated); *rules* (very dense, solid materials sink); *generalizations* (most samples of wood float); *principles* (the buoyant force acting on a submerged object is equal in magnitude to the force of gravity on the displaced fluid – Archimedes' principle); and *laws* (the buoyant force and the gravity force acting on a floating object are equal in magnitude – law of flotation).

Nature of scientific inquiry

Scientific inquiry involves methods of investigation that often include an empirical component and a theoretical component. Such components may not be obvious to students until they are well into the Intermediate Division. They may be illustrated by a question such as the following: "How long can a lupine seed maintain its ability to germinate – 1, 10, 100, 1000, ... or a million years?" By experimenting and observing (empirical investigation), students can find evidence to help answer this question as it applies to the one-year, ten-year, or even the hundred-year period. However, some lupine seeds, suspected of being 10 000 years old, have been seen to germinate. The assumed age of the seeds may be based somewhat on theory. For a million-year period, the theoretical component would have to dominate the investigation.

The empirical component of an investigation involves testing an idea and observing the results, a common activity in a science course. This method of investigation involves:

- a clear statement of that which is to be tested;
- the design and performance of a test;

- the accumulation of observed results;
- an interpretation of these findings; and
- a conclusion regarding the stated investigation.

Empirical investigations are often “linear”, moving in a specific direction from an initial statement to a final conclusion. Empirical investigations often contain a theoretical component. Examples of empirical investigations are contained in such hypothetical statements as: “The majority of girls in the school have brown eyes,” and “10 g of salt will dissolve in 100 g of water, as will 10 g of sugar, baking powder, starch, calcium carbonate, and potassium permanganate.” A hypothesis is not necessarily true.

The theoretical component of an investigation may involve the statement of a theory; a prediction or deduction related to the theory; an empirical test, if possible; and an examination of the results, which may answer the problem, reinforce the theory, or require the formulation of a new or revised theory. For example, to investigate the answer to the problem, “Why do dinosaurs not exist today?”, a hypothesis would be devised; related data would be collected; empirical testing, if any, would be limited; the results would be evaluated; and a tentative conclusion would be formulated. The theoretical component of an investigation can involve hypothesizing, problem-solving, decision-making, speculating, testing, and a reworking of the theory. Such investigations are often “circular”, moving from a problem to a speculative idea to predicting, testing, evaluating, and reassessing, and back again to a reinforcement of the original theory, a revision of it, or a replacement of it with a new one.

Regardless of the method used, students should experience the exhilaration derived from discovering the explanation of previously mystifying events as a result of their own experiments. The mutuality of the teaching process is such that both teacher and student may share in the enthusiasm, satisfaction, and enlightenment that come from the activities of science. The science laboratory is not bounded by four walls: it includes the students’ own bodies; the organisms and materials with which they interact; the flora and fauna; the land and water; the atmosphere and the heavens. It is expected that student interest and achievement in science will go beyond the classroom through field trips, class visits, science fairs, and personal explorations.

Nature of scientific explanation

Science courses should incorporate explanations of natural phenomena that make use of logical statements, theories, and models. Logical statements are based on facts, definitions, laws, and related conclusions. The following sentences are an example of a logical set of statements. “A freely falling object has a net downward force acting on it. Therefore, its downward speed increases as it approaches the earth, and hence, its kinetic energy increases and its potential energy decreases. This means that while it is losing one kind of energy it is gaining another.”

The scientist requires theories to explain such phenomena as the boiling of water at a unique temperature (at a given pressure). In this case, the kinetic molecular theory provides a satisfactory explanation. Models are also a means of explaining natural phenomena. For example, a model of the atom could help to explain why some elements combine more readily than others.

Students should be required to test explanations. If it is proven correct, an explanation should permit accurate predictions. For example, if the theory of evolution is to be accepted as accurate, scientific evidence of an indisputable nature must be available and must be thoroughly tested

before the theory can be stated as a factual explanation. Both the strengths and weaknesses of a theory should be examined. Science requires that a good explanation have the property of predictability and does not, for example, attribute events to unpredictable influences of the zodiac, to the uncertain workings of capricious gremlins, or to unfounded superstitions.

A Developmental Program

The science program must be developmental. It must allow students to develop their academic knowledge, their skills (both intellectual and practical), and their ability to solve problems. As well, it should help them to develop good attitudes and to make sound value judgements on issues related to science.

Scientific literacy

The understanding of scientific expressions and terms, definitions and laws, concepts and principles, conventions and classification schemes, theories and models, and conceptual schemes is usually one of the main objectives for students of science. For example, in addition to their spelling and using the word “photosynthesis” correctly, it is essential that students understand the process, recognize its applications in nature, and apply their knowledge of the process to further studies. As students meet various terms and expressions over and over again, it is expected that their understanding of them will expand.

Students should be able to apply scientific knowledge to practical situations in their everyday lives. Too often, scientific knowledge that is acquired in the laboratory is not applied outside. Students should be encouraged to seek examples of applied science in the world about them. They should come to see how science interacts with other areas of life, such as athletics, recreation, travel, economics, the arts, industry, construction, transportation, consumer products, control of disease, mental health, energy resources, and politics. Many students are involved in hobbies or leisure-time activities of a scientific nature. The experience of such students can enhance the curriculum.

Scientific skills and processes

Students should develop certain skills, often requiring manipulative techniques, that will enable them to increase their understanding of science. They should learn to:

- measure (in SI units) length, volume, mass, time, temperature, and force, using appropriate measuring devices, with a reasonable degree of accuracy;
- measure the dimensions of microscopic specimens;
- tabulate data in a meaningful form;
- develop graphs of both given and experimental information;
- illustrate scientific structures with suitable drawings;
- manipulate and use a hand lens and a microscope;
- prepare and handle wet- and dry-mount slides;
- perform staining techniques for microscopy;
- prepare biological specimens for microscopic examination;
- perform simple dissecting techniques;
- safely operate heat sources;
- correctly use electrical apparatus;
- efficiently handle mechanical devices designed for field and laboratory investigations;
- safely handle laboratory glassware;
- properly and safely prepare, collect, and test certain gases, such as oxygen;

- safely handle and store chemicals;
- wisely use devices that require electric, thermal, or chemical energy in an effort to reduce energy wastage;
- handle living plants and animals with care.

Processes

Students should use the following well-tried intellectual processes in the learning and doing of science:

- identifying problems;
- developing hypotheses;
- designing experiments and methods of testing;
- identifying, manipulating, and controlling variables;
- organizing and processing data;
- interpreting and explaining findings;
- proposing theories and forming models;
- formulating generalizations;
- inferring relationships;
- evaluating conclusions;
- substantiating hypotheses;
- understanding conceptual schemes.

Solutions to problems

Students should be encouraged to solve problems relating to the qualitative attributes of objects. Such work will enable them to acquire manipulative skills and to develop intellectual processes. Students should be given opportunities to:

- read and write;
- observe and describe;
- listen, feel, taste, and smell;
- identify and classify;
- compare and list in order;
- design and construct;
- find examples and applications;
- ask sensible questions.

Quantitative problem-solving should also be an important part of the science program. Students should be able to perform straightforward arithmetic and algebraic operations and to solve simple equations based on scientific relationships. The following should be part of the program:

- All measurements should be done in SI units.
- Estimating should play a major role in measurement activities.
- Students should become familiar with scientific notation and the meaning of significant digits, approximation, and rounding.
- Ratio and proportion, decimal, percentage, and exponential notation should be widely used.
- Mathematical, chemical, and metric notation should be used correctly in accordance with accepted conventions.
- Tabulating and graphing activities should be frequently emphasized.
- The use of hand calculators should be encouraged, particularly to check calculations by means of an inverse operation. For example, if a student calculates the speed of a hotwheel by dividing 32.2 by 18.4 and arrives at a numerical answer of 1.75, he/she should learn to check the result by multiplying 18.4 by 1.75 to see if this product is 32.2. Students should also learn to include units of measure in a problem, when desired. For example, $v = d/t = \frac{32.2 \text{ m}}{18.4 \text{ s}} = 1.75 \text{ m/s}$.

Students must be given opportunities to conduct many inquiries and in so doing to develop and apply good attitudes and values towards science-related issues. The example set by the teacher is often the most important means of achieving this objective. The following attitudes towards scientific endeavour should be encouraged:

- curiosity towards the new or unknown;
- honesty in investigation and realization of the limits of science;
- willingness to have techniques examined and questioned;
- risk-taking in developing a new approach;
- desire for precise, accurate measurement, including the double-checking of results by alternative methods, and a high calibre of reporting;
- confidence and pride in work well done;
- satisfaction in scientific inquiry, though it be challenging, difficult, or even discouraging;
- consideration towards others when working on a team, showing willingness to consider suggestions and theories proposed;
- willingness to share findings and to coach fellow students;
- respect for and interest in the scientific inquiries of the past and the people who have given us our scientific heritage;
- concern for conserving energy and materials, including the prevention of pollution, the maintenance of safety precautions, the thoughtful care of plants and animals, and the proper treatment of scientific apparatus;
- desire to use one's scientific interests in the advancement of human welfare.

Science courses should include some problems of social, ethical, or environmental concern to allow students to examine their own values regarding various scientific issues. They might be asked to give their opinions, for or against, and to debate such issues as those suggested by, the following statements:

- Hunters should not be allowed to hunt.
- Starlings should not be massacred even though they are pests.
- The swine-flu vaccine is harmless and should be mandatory.
- Mercury poisoning in our lakes is overrated.
- If we can pay for energy, we should be able to use it.
- People who are suffering from an incurable disease should be permitted to choose euthanasia.

These and similar topics can be used to enrich science and to involve students in the consideration of value judgements or defensible decisions.

Another approach is to have students place a series of ideas in order of considered importance or to award points to each idea (say, out of ten) to indicate its relative value. For example, how many points, for or against, would they award for each of the following acts related to the wise or unwise use of energy?

- washing a car by pail, rather than using a hose
- using an electric razor in place of a safety razor
- drying only one pair of gloves and jeans in an automatic clothes dryer
- allowing the tap to run freely when brushing teeth
- keeping the hot-water tank set as low as is convenient
- drying clothes on a clothes line
- driving to the corner store to buy some chewing gum
- using an elevator rather than walking up two floors
- going to work in the summer on a bicycle
- setting the thermostat at 22°C
- keeping the Bunsen burner at its maximum setting in order to maintain a beaker of water at the boiling point

Some Learning Objectives in a Science Program

Introduction

This section is intended to assist teachers and curriculum committees to formulate their objectives for the science program. The illustrative set of objectives presented here is simply a sample list. Curriculum designers should use it as a checklist of the many facets of science instruction that go beyond the learning of subject matter.

The chart at the end of this section is a summary of the learning objectives described herein; it may be useful in assessing those objectives that are applicable in the treatment of any given unit. If such a chart is used to assess a set of units of study, it may reveal areas of over- or underemphasis; topics can then be realigned until a better balance is found.

Part A of this document referred to objectives in terms of knowledge, skills, and attitudes. Here, a slightly different view is taken: objectives are related to the domains of *knowing*, *understanding*, and *appreciating*.

Knowing is the appropriating of information. It allows students to recall or identify textual data, techniques and observations, or class discussions in much the same way as they are provided in textbooks, laboratory reports, or written notes. *Understanding* is applying or making use of knowledge. It includes such processes as classifying items, inferring results, forming generalizations, reaching conclusions, postulating theories, and applying scientific knowledge to practical situations in the world. Understanding can also include the ability to demonstrate certain practical skills in scientific work, such as the ability to do an experiment. *Appreciating* is valuing scientific knowledge and skill and having a positive attitude towards the environment, living things, and natural resources. It includes the enjoyment and satisfaction gained through knowing science, understanding it, and using it for beneficial purposes.

These three domains – knowing, understanding, and appreciating – may not include all possible learning outcomes, but they are useful in the classification of some objectives or outcomes in the science program. The objectives identified in this section may be classified in more than one domain and may be organized differently from the way in which they are presented here.

Knowing

In a science course, students should seek to know a good deal of science, such as facts, terms, concepts, principles, theories, and so on. They should also know about the scientific enterprise – the human process of developing scientific knowledge and putting it into use. This includes the learning and promoting of science by the scientific community – people who are involved in scientific activity of one kind or another. This implies that students should know about scientific knowledge and how it is gained, promoted, shared, and applied. In the following twelve areas related to knowing, the first six deal with science itself and the last six with the development of scientific knowledge.

Facts

Factual information includes the descriptions and observations of natural phenomena and the ordering of phenomena in their correct sequence of occurrence in nature. Facts also include scientific investigations involving experimental manipulation. The following are examples of facts:

- Water is a solid at a temperature below 0°C.
- Plant cells have a rigid outer covering.
- A caterpillar turns into a butterfly or moth.
- The volume of a gas decreases as the external pressure increases.

Terms and concepts

These are words that have special meaning in the scientist's vocabulary. They identify an item or a phenomenon; they summarize a property or a set of events; or they condense important common features of a large set of facts. Examples include: cell, molecule, solution, metre, igneous, inorganic, exothermic reaction, mammal, buoyancy, precipitation, energy, genetics.

Conventions

These are arbitrary practices that have been adopted by scientists to facilitate the recording of, communicating of, and working with data. Signs, symbols, and abbreviations have specific meanings and are used in certain ways. The following illustrate scientific conventions:

- Standard air pressure is 101.325 kPa.
- N and S denote magnetic poles.
- $D = m/V$
- H_2O
- $\Delta E = mc\Delta T$

Classification schemes

Many items and phenomena in science are grouped into categories according to some system. These categories are distinguished from one another by using rules called criteria. The following are examples:

- Matter is classified into the following categories: solid, liquid, and gas.
- Living things are grouped into the following kingdoms: moneran, protist, fungi, plant, and animal.

Principles and laws

These are generalizations derived and established from a large number of related observations. They are based on empirically confirmed relationships. Examples include: Bernoulli's principle, Archimedes' principle, Mendel's laws of heredity, Boyle's law, the law of the lever.

Models, theories, and conceptual schemes

These are broad generalized statements which summarize scientists' explanations of observed aspects of the universe. Such ideas are built on assumptions and postulates. A model or theory serves several functions in science: two of these functions are (a) to account for or to explain observed phenomena; and (b) to suggest new hypotheses, problems, and investigations that will give direction to further inquiries. Examples include: Darwin's theory of evolution; the kinetic molecular model of matter; the conceptual scheme that matter exists in the form of units that can be classified into hierarchies of organizational levels.

Nature of scientific knowledge

Beyond actually knowing science content, this area deals with knowing something about that knowledge. Scientific knowledge has certain characteristics. It is:

- humanistic – devised by people seeking to find patterns in, and explanations of, natural phenomena;
- historical – present knowledge is a revision of past findings and forms the basis for future research;
- replicable – different individuals working independently would arrive at similar conclusions from the available evidence;
- probabilistic – frequently an element of probability exists, particularly when a theory or model is applied to a real situation;
- holistic – various specialized sciences contribute knowledge to an overall world view;
- empirical – scientific knowledge is derived from observations and experiments, and these are used to evaluate theories and models.

The following examples may illustrate each of these characteristics respectively: the classification and origin of living things; the story of the atom; the comparison of American and Russian space missions; the probability of having blue eyes; the field of medical technology; the evidence and subsequent explanation of the formation of crystals.

Historical aspects

Students should know about some historical developments in the formation of scientific knowledge. These may include the contributions of scientists, the historical growth in knowledge, and the cumulative nature of knowledge. Examples include: Mendel's laws of inheritance; Newton's first law of motion; the development of a model for DNA (deoxyribonucleic acid); the formation of the periodic table; the expansion of uses of electricity; the spread of the use of SI units on a global basis.

Nature of scientists

Students should know something about scientists, whose professional work involves the development of knowledge. Scientists differ from other people primarily in the nature of their training and experience. Their lives, personalities, and activities are of interest. The following are examples from the personal lives of scientists that could be presented:

- Celsius loved to watch the northern lights.
- Marie Curie possessed an amazing devotion to research.
- Galileo suffered persecution for his scientific claims.
- Joule operated a brewery.
- Leeuwenhoek lived to the venerable age of ninety-one (1632-1723).
- The importance of Mendel's work was not recognized until 1900, fourteen years after his death.
- Pascal wrote a great deal about religion.

Aims of the scientific enterprise

Here, the learner is expected to know something about the public development of science in general. The scientific enterprise increases human understanding through the explanation of natural phenomena in terms of principles, models, and theories. Scientific societies promote and exchange ideas, maintain professional standards, and promote scientific work. Many people are exposed to new scientific developments through the media, continuing education, on-the-job training, science fairs, clubs, and associations. Examples include: the National Research Council; various associations in biology, chemistry, physics, astronomy, geology, and related fields; the Science Teachers' Association of Ontario; science TV programs; local, provincial, and national science fairs.

Technological applications

Pure science deals with the development of knowledge, whereas applied science deals with practical assignments of such knowledge. Just as an increase in the knowledge generated in pure science can result in new applications through technology, a new instrument or technique perfected through technical expertise can lead back to further growth in scientific knowledge. Thus, both science and technology (applied science) are interdependent, and students should know something of their interplay. Examples of applied science include: the development of various types of microscopes; the applications of electronics to produce such items as television and hand calculators; the misuse of poisonous gases and napalm; the use of isotopes; the benefit of vaccines and antibiotics; the use and misuse of drugs; the growth of passenger air transportation.

Societal implications

Scientific and technological developments are influenced by prevailing cultural, economic, social, and political conditions. The priorities, interests, and financial support of people can influence research. As well, human values are tempered by the applications of scientific ideas. The resulting issues can involve decision-making, compassion, tolerance, sacrifice, morals, religion, politics, customs, and culture. Students should be exposed to the societal implications of science through such topics as the DNA-recombination experiments to "produce" life; heart transplants; swine-flu vaccine; the concepts of creation and evolution; the use of nuclear weapons; the conservation of energy resources; the folklore concerning the origins of the earth, stars, rain, and fire.

Understanding

If *knowing* is appropriating information, *understanding* is putting knowledge into use. To know a scientific fact is commendable, but to understand it in a useful, applicable manner is much more desirable. "Understanding" is defined here as the intellectual and practical process whereby a person demonstrates his/her grasp of some knowledge. This may be done by explaining a phenomenon, solving a problem, devising an investigation, forming a generalization, reaching a conclusion, applying a principle, or selecting a technique and putting it into practice. There are many other ways by which students show that they are understanding science and not merely knowing the subject. The following areas can indicate an understanding of scientific knowledge.

Terms and conventions

As well as knowing certain scientific terms and conventions, students also require an understanding of their correct use and an ability to spot incorrect uses. For example, they should be able to indicate what is wrong with the following:

- Two machines must generate equal power if they exert equal forces.
- The relative density of water is 1 kg/m^3 .
- Respiration and breathing are entirely different processes.

Facts and concepts

A fact or concept may be learned by rote memory, but this may produce a very weak understanding, if any. Comprehension is displayed when students apply the knowledge of a fact or concept to a new situation on their own. For example, a student decides that a tomato is a fruit or that water sometimes provides an exception to the rule that liquids expand when heated.

Classification schemes

If classification schemes are understood, students should be able to examine new items and to classify them without being told the answers. They will require a knowledge of the criteria to be used and a recognition of the characteristics used to sort the items into various groups. Such applications include the classification of living specimens of animals and the identification of various types of rocks and minerals using real samples.

Observation and description or explanation

This involves the use of the senses not only to receive information, but also to understand something about the item or phenomenon observed. The new acquisition of knowledge is then expressed in a description or explanation. The following situations are examples of this process:

- A student drops a marble into a graduate containing water and mercury (prepared by the teacher) and observes, describes, and explains what is seen.
- Iodine is added to various foods and the resulting changes in colour are observed and simply explained.
- Copper sulphate crystals are heated, and the changes are noted and explained by the student.

Measurement and estimation

The measuring of a quantitative characteristic often requires a clear understanding of the property to be measured and the technique to be applied. Accuracy and precision may be involved, or a reasonable estimation may be all that is needed. In any event, understanding is subject to question if an estimate cannot be made. Examples include finding the area of a pond; the width of a paramecium; the volume of a rock; the density of sand; the speed of a toy vehicle; the force exerted by a magnet; the work done in climbing a rope; the temperature losses and gains when hot and cold substances are mixed.

Principles, laws, models, theories, and conceptual schemes

Understanding requires that students comprehend the distinction between principles and laws on the one hand and models and theories on the other. Students should be able to recognize applications of, or to state the generalization that governs, a particular example. They should perceive schemes that embrace a wide variety of phenomena. Thus, they should be able to answer such questions as the following:

- Are the rules that govern heredity laws or theories?
- Can changes of state be explained by a principle or a theory?
- What general principle, if any, helps to explain why a rock splits in winter?
- Give three examples of conceptual schemes.

Laboratory procedures

There are times when students should follow instructions “cookbook-style” when doing experiments in the laboratory, but this alone is insufficient. Students should understand why certain procedures are better and safer than others, and why some are valid and others not. The proper care for apparatus should be well understood, supported by reason rather than blind concurrence. Examples include: the adding of acid to water, not water to acid, to dilute the acid; the heating of chemicals in glassware; the connecting of electrical circuits; the preparation of microscope slides; the dissection of animals.

Identification of problems

The starting point for an inquiry may pass through several stages, from the initial awareness that there may be a problem to its specific identification. Understanding that there is a reasonable problem, that it must be clearly enunciated, how it may be tested, and whether it can or should be tested are important issues related to this learning objective. For example, does hot water cool faster in a paper, plastic, or styrofoam cup? Does it cool faster in two paper or plastic cups than in one styrofoam cup? For what reason may this be a worth-while investigation? Can it be tested in the laboratory? How?

Development of hypotheses

Generally speaking, a hypothesis is a tentative statement to be checked by a subsequent test. Once a specific problem has been identified, several plausible hypotheses may be suggested. Understanding is demonstrated when students suggest plausible hypotheses for solving a particular problem and then order them from most probable to least probable. It may not be possible to test some hypotheses in the laboratory; this should not necessarily disqualify them. For example, suppose that the newspapers report that Canada will be overrun by cats and dogs by the year 2000. A student might hypothesize that the statement is false and should be ignored; that birth control measures should be enforced on the animals; that the excess animals over certain legal limits be painlessly exterminated; that cats and dogs have as much right to live as do humans and that overpopulation should be permitted with the resulting consequences. Such hypotheses can then be useful as starting points for further work.

Design of experiments

The designing of experiments generally involves a clear understanding of the controlling and testing of variables. The identification of each variable, the controlling of an independent variable, and the observation or measurement of the dependent one require careful thought and design. Students must recognize any new variable that may be introduced inadvertently. Such situations include, for example, determining the factors that influence how much a ray of light is refracted; how friction may be reduced; how a plant may become healthier; how a chemical reaction may be slowed down.

Organization and treatment of data

This involves an understanding of such activities as presenting a laboratory or field technique; giving an explanation or report in a logical sequence; organizing information in charts and tables; using graphics such as drawings and graphs; and solving mathematical problems to obtain the required data. These skills are required in such tasks as explaining the circulatory system of an animal; listing the relative solubility of a number of substances; indicating the parts and corresponding functions of a flower; showing the rate at which a plant grows; and calculating the power generated by a machine that lifts a load.

Interpretation of data

Students should be able to find a pattern or some other meaning inherent in a collection of data. Some interpretations may lead to generalizations, some to the acceptance or rejection of a hypothesis, others to the statement of simple facts, and still others may result in open-ended conjectures, with some denying that any worth-while results have been achieved. The interpretation of data often includes the skills of making operational definitions and of interpolating or extrapolating. The following are examples of the interpretation of data:

- The evidence shows that all of the sample gases expand at about the same rate when heated. It is tentatively assumed that all other gases behave in a similar manner (open-ended).
- We can operationally define “quantity of heat” by means of the equation $Q = mc\Delta T$.
- From the given data, it is impossible to forecast what weather we will have one week from now.
- If the temperature is increased another 5°C, the amoeba will die.

Evaluation of hypotheses

This requires students to answer the question: “Are these findings consistent with the hypotheses?” Students should constantly attempt to understand the purpose of an investigation and to work in this direction. If an unexpected result occurs, they should reassess the findings, perhaps repeat the investigation, and search for some explanation; they should not discard the unexpected result. A hypothesis is not necessarily a poor one just because it is disproved. A re-evaluation of the hypothesis may lead to its revision or to the formation of a new one. The following are some examples:

- A student hypothesizes that the period of a pendulum will decrease if the mass of the bob is increased. (The data show that this is not true.)
- A student hypothesizes that both mass and volume are conserved when alcohol and water are mixed. (This is partly true and partly false.)
- A student hypothesizes that water contracts as it cools and finds ample data to support the hypothesis except for one point on his/her graph. (The student requires more data.)

Formulation of generalizations

Students must understand that science often leads to the forming of generalizations that are subject to possible revision. They should compare experimental results with classmates, carry out additional investigations with different materials or under a variety of conditions, and check the results of similar work as presented in textbooks and other resources. Even if their original findings are corroborated, students should understand the limits that govern empirical generalizations. The following are examples of such generalizations:

- All samples of the wood tested float in water.
- At least 30% of the residents in Ontario have brown eyes.
- Sugar is more soluble in hot water than in cold water regardless of the temperature selected.

Formulation and evaluation of models and theories

If students are to understand a certain phenomenon, their comprehension can often be enhanced by the creation of a model or theory. Models or theories should “explain” the observations and generalizations to which they apply and may lead to new hypotheses, problems, and investigations. Models and theories are frequently based

on analogies and representations and should be subject to constant evaluation and revision, if necessary, as new data become available. For example:

- The theory of evolution is an extrapolation into the theoretical past and is under frequent revision.
- The conduction of heat may be represented and explained by a model of colliding spheres, which suggests that as the density increases, heat transfer becomes more rapid.
- An early model of the atom may suggest that helium, neon, and argon are “inert”, but this idea is now under revision.

Nature of scientific knowledge

This learning objective allows students to understand why a particular approach to science has been adopted. Scientific knowledge was characterized on page 37 as humanistic, historical, replicable, probabilistic, holistic, and empirical. These and other characteristics should give students an insight into why and how knowledge has been developed. They should answer such questions as:

- Why did Galileo defy the teaching of Aristotle?
- Why did scientists initiate space flights?
- Why is there such an effort to develop genetic engineering?
- Why did humans make nuclear bombs?
- Why produce harmful drugs?
- Why do people study the stars?

Interrelationships

The understanding of the interrelationships between scientific knowledge, its technological applications, and any societal implications should be part of the science program. Such statements as the following could be discussed in this context:

- Science favours transition to the metric system, which necessitates changes in industry and society.
- People are concerned about prolonging the life of a person by means of a machine.
- We are too extravagant in our use of energy resources, but we are doing little to solve the problem.

Appreciating

Attempting to encourage students to value their learning of science and to develop positive attitudes towards applying their learning to practical situations is indeed a challenge, but a challenge that should be a vital part of the science program. It is not enough to know and understand. In any science course, there is the potential to include elements that involve such human characteristics as honesty, curiosity, thoughtfulness, openness, objectivity, carefulness, perseverance, reliability, initiative, confidence, industry, satisfaction, tolerance, respect, and co-operation. Students should learn to appreciate opportunities to develop positive attitudes towards such areas or groups as learning, inquiry, theory, people, animals and plants, the environment, applied science, and the scientific enterprise.

Learning

Students should be encouraged to develop an attitude of curiosity, a respect for knowledge, a desire to achieve, a sense of confidence, an openness to evaluation, and a willingness to accept responsibility in all areas of the science program. A student who exemplifies these traits may be curious about the lines formed by rocks in a precipice; subscribe to a

number of science periodicals related to geology; produce well-organized reports on earth science; give plausible arguments when explaining the composition of rocks; accept valid criticism when theorizing about the formation of the earth's crust; and enjoy working diligently and maintaining a standard of excellence in science.

Inquiry

This learning objective deals with attitudes that are part of the spirit of scientific inquiry and is difficult to identify. Although intellectual processes are involved, these do not always become observable through psychomotor response. Yet certain behaviours may be considered reasonable indicators of good attitudes. An exemplary student might observe details and characteristics of leaves and then classify them; wonder why some leaves turn yellow and others red and then formulate a hypothesis; be willing to read or ask about this problem; seek to design some relevant investigations, even on his/her own time; welcome criticism and evaluation; consider new evidence; realize that conclusions are tentative and subject to revision; and keep searching for further answers to the problem.

Theory

Generally speaking, factual knowledge is readily substantiated and relatively easy to accept. On the other hand, theories and models are sometimes problematic and are often totally rejected or totally accepted by adolescents. Students should develop an attitude of respect for theoretical structures; they should demonstrate an awareness of their importance as a means of relating information, explaining phenomena, and generating new knowledge; and they should realize the inadequacies of any theory. The following example demonstrates the outcome desired: A student learns to respect the theory of population change as applied to a rabbit population – a theory based on density-dependent environmental factors. He/she realizes the importance of this theory in explaining and working with many different populations and appreciates the fact that the theory may not explain changes in the populations of ants. This realization, that a theory could be inadequate, is an important scientific attitude.

People

Students should appreciate their fellow students, the school staff, and all others with whom they interact in their science endeavours. They should enjoy an environment of honesty, co-operation, and openness to criticism, where ideas are shared, other students are assisted, and good suggestions are accepted from others. An exemplary student will ask about mathematical problem-solving in science when in doubt; will admit his/her weaknesses; and, when the problems are well understood, will be willing to explain them to other students.

Animals and plants

Students should enjoy the study of nature and develop a respect for all forms of living things. Such a student will care for classroom animals during school holidays; will not tamper with plants when on an outing; and will seek to prevent cruelty to animals at all times.

The environment

Students should develop an increasing appreciation of the environment – of its life-sustaining properties, its wealth, beauty, design, and balance. They should seek ways to keep the environment unpolluted and to preserve its natural resources. Examples would include students in a cottage area who conduct a campaign to stop pollution of a lake, or students employed at a campsite who decide to show films on the wonders of nature.

Applied science

Students should become willing to apply the basic information and processes learned in the science program to issues involving personal and public decision-making, while at the same time recognizing any limitations that may exist. The emphasis here is on the willingness of students to voluntarily apply their scientific knowledge and skills outside of the laboratory. Such a student might reduce the consumption of energy at home by drying wet clothes on the clothes line in good weather; by washing the car from a pail of hot water and rinsing with a hose only when necessary; by mowing the lawn with a hand mower rather than with a power mower; by turning off lights when they are not needed; by using a mug of water rather than a running tap when brushing teeth; or by finding drafts around windows and doors and doing something about them.

The scientific enterprise

Students' value systems could be affected through an appreciation of the scientific enterprise. Students should respect the work of scientists who have sought to find solutions to problems in the past and continue to do so. Students should seek to further the cause of science by maintaining an interest in scientific matters that are newsworthy and by sharing such items with others. Some students will seek to follow a scientific vocation or to engage in science-related leisure-time activities. As well, students should express reasoned opinions on issues of social concern that are related to science. Such a student might be enthused by the devotion and work of Marie Curie; he/she might become increasingly interested in pursuing a career as a chemist; and he/she might voice concern over the mercury pollution of our lakes.

Summary

The following chart may be used as a checklist of some desirable learning objectives for any unit of study selected for the science program. If a specific objective is consistently missing from a number of units, opportunities should be sought to implement it in others.

Some Learning Objectives	
Unit title	
Grade	
Checklist	
	Knowing
	Facts
	Terms and concepts
	Conventions
	Classification schemes
	Principles and laws
	Models, theories, and conceptual schemes
	Nature of scientific knowledge
	Historical aspects
	Nature of scientists
	Aims of the scientific enterprise
	Technological applications
	Societal implications
	Understanding
	Terms and conventions
	Facts and concepts
	Classification schemes
	Observation and description or explanation
	Measurement and estimation
	Principles, laws, models, theories, and conceptual schemes
	Laboratory procedures
	Identification of problems
	Development of hypotheses
	Design of experiments
	Organization and treatment of data
	Interpretation of data
	Evaluation of hypotheses
	Formulation of generalizations
	Formulation and evaluation of models and theories
	Nature of scientific knowledge
	Interrelationships
	Appreciating
	Learning
	Inquiry
	Theory
	People
	Animals and plants
	The environment
	Applied science
	The scientific enterprise

Rationale for Science: A Student Viewpoint

There are many reasons for an Intermediate Division student to choose to study science. Here are a number of possible ones:

- Science enables you to know a lot about a lot of things, and knowing can feel great.
- Science lets you use your eyes in a new way. You can see the stars through a telescope or germs through a microscope, and previously invisible worlds become fascinatingly visible.
- Science has its great men and women, and this human endeavour, this creative opportunity, can help you to be creatively intrigued with the past, the present, and the future.
- Science can help you to grow intellectually, because it lures you to guess and question, to wonder and grope, and to try to fathom the depths of simple mysteries.
- Science helps you to respect evidence – you can guess and hypothesize and predict and infer, but eventually you may want the facts and then either you find them or you keep on searching.
- Science has been the basis for many discoveries or achievements: some make you glad – penicillin, solar cells, vaccines, electric bells, microscopes, and organelles; others make you sad – atomic bombs, pollution, thalidomide babies without solution, pesticides without dilution; so you try to accentuate the positive and eliminate the negative.
- Science begs you to experiment: to boil leaves in alcohol, to watch acids eat metals, to swish a cloth out from under a bowl of jelly; you can learn by doing, by making silly mistakes, and then by redoing the job properly.
- Science can prick your social conscience – to waste or not to waste? To have a deep bath or a short shower? To turn out the light or to leave it blazing needlessly? To avail yourself of every modern convenience or to exercise a little muscle? To blast the air with exhaust fumes or to walk to the store? To be considerate or indifferent?
- Science lets you look in your rear-view mirror and can make you wonder how your forebears ever got along without television sets, cars, radios, telephones, antibiotics, hand calculators, electric blankets, and automatic dishwashers. Or were they so unfortunate?
- Science can make you smell the perfume of a flower, the scent of a skunk, the odour of hydrogen sulphide, the aroma of honey, the pungency of ammonia, and the antiseptic sleepiness of ether – your nose is never the same after it sniffs science!
- Science encourages you to assess your own achievements, to check your own failures, to try again, to plan constructively, to design your methods of investigation, to be sure that during the next dissection you will obey instructions properly and observe more closely and think more acutely.
- Science urges you to explore the environment, to unearth its secrets, to wonder where the cardinal lives, how the bee manages to fly, why rivers flow forever, where the sunset gets its splendour, why the flowers face the sun, and why apples bruise themselves by falling downwards instead of sideways.

- Science can show you a continuum, from simple patterns to complex networks, from basic laws to systematic operations – how three primary colours can form a myriad of blends; how Newton’s three laws explain the trajectory of a missile; how electrons, protons, and neutrons can be used to explain almost everything.
- Science challenges your thinking powers, and you may want to classify animals, identify the types of clouds, hypothesize about the motion of planets, analyse the workings of an engine, or synthesize the bones of a skeleton.
- Science demands that you work well with others, that you share your findings with the class, that you not despise the discoveries of your predecessors, that you not overheat the test tube while your partner is trying to collect oxygen, that you learn to give and take, and that you show concern for the safety of your fellow students and of yourself.
- Science can teach you that “scientific explanations” may be false, incomplete, biased, tentative, or reliable, that eventually they must be based on substantial, reproducible proof, and that theories may or may not be adequate. You still wonder what really did happen a billion years ago.
- Science can intrigue you into wanting to read, to do research, to report your findings, to communicate well, to substantiate your claims, to graph a series of observations, to solve puzzles and problems, and to present clear, concise, and well-organized reports.
- Science can challenge you to be critical in analysis, careful in judgement, cautious in prediction, and, it is to be hoped, sure when hopping (rather than jumping) to conclusions.
- Science can help you to develop a good imagination; you make up models to explain what you’re thinking about. Sometimes you find that you can’t explain something to a friend or even to yourself, so you say “It’s like this – this model, not the real thing, you know, but here’s what it could be like.”
- Science may influence your attitude towards a personal respect for animals and plants, care of scientific apparatus, conservation of energy resources, and a concern for such problems as hygiene, overpopulation, disease, drugs, and weapons of warfare.
- Science beckons you to enjoy life and to appreciate nature: the majesty of a tree, the power of a wave, the beauty of a crystal, the song of a bird, the colour in a leaf, the motion of a snake, the delicacy of a spider’s web, the beat of a heart.
- Science makes you leap from the concrete to the abstract, from using numbers to allowing variables to vary, from focusing on a change to realizing the simultaneous effects of several changes.
- Science can give you a vision of a system rather than leaving you to squint at a single entity – you can understand the interdependency of living things, not just how a rabbit survives; you can grasp the kinetic molecular theory and are no longer satisfied with saying that water boils because it has reached 100°C; you suddenly see the whole coherency of SI, not just the metre.

- Science makes you curious about human bodies – you enjoy watching a girl become a woman or a boy become a man; you try to imagine what happens to ingested food; you wonder what experiences a blood corpuscle must go through; you are convinced that your brain is a biological wonder.
- Science permits you to find a wonder-world of relevant and amazing phenomena that becomes yours through your joy of discovery, through your satisfaction with work well done, through your aspirations for discovering the truth, and through your hope that people will channel science into good rather than evil.
- Science is worth it – especially when you come in contact with an inspiring science teacher.

Methods of Evaluating Student Achievement

The Purpose of Evaluation

Student evaluation is used by teachers to help them to understand their students' needs; to indicate students' skills, understandings, attitudes, and interests; and to provide feedback on the effectiveness of the instructional program.

For students, evaluation is useful to confirm their achievement and growth; to identify strengths and weaknesses; to show evidence of their achievement in school for parents, other educational institutions, and employers; and to provide self-motivation.

Parents make use of student evaluation to follow the progress of their sons and daughters; to obtain an independent and generally recognized indication of scholastic attainments; and to help the young people in future undertakings.

An evaluation system should utilize information that can be recorded while students are being observed in a busy classroom. Therefore, it should not be restricted only to written tests; it should underline how a student best learns, rather than emphasizing the student's relative position or speed of learning; it should indicate growth, rather than failure; it should point out achievements in independent learning; it should provide an adequate basis for teacher-student conferences so that a teacher can assist a student in remedial or in-depth work where desirable; and it should constantly recognize the goals of the science program of the school.

The Process of Evaluation

The process of evaluating student progress should be closely tied to the objectives of the curriculum. These objectives should be formulated independently of the methods of evaluation that will be used to test their attainment. However, the question of evaluation should immediately follow the formulation of objectives. Where such evaluation turns out to be difficult, it should not be interpreted as indicative of a weak objective, but rather of an inability to create a satisfactory evaluative instrument.

Evaluation should be a continuous, integral part of teaching. It should not be restricted to a test at the end of each unit and an exam at the end of each term. Frequent and varied tests of one kind or another can be given: perhaps a single problem here, a simple activity there, a puzzle to be solved, a phenomenon to be explained, a hypothesis to be formulated, or an opinion to be given.

At times, self-evaluation can be useful and may stimulate the achievement of realistic goals. Students can find out how much they have learned, how skilful they are, and what processes they can apply. With teacher assistance, students can evaluate their self-reliance and social responsibility in science activities. They can be given a questionnaire to complete at home. The answers would then be supplied the following day in class with students marking their own papers. The papers need not be handed in. The students are required to act on their own behalf. This suggests implicit faith in them and their ability to examine themselves and then to consider the consequences realistically. A major purpose in evaluating students should be to teach them to evaluate themselves.

Some Techniques of Evaluation

There should be a good variety of evaluation techniques in any evaluation system. Twenty different techniques are suggested below. They range from simple items that require one-word answers to those that ask for essay-type reports. Some techniques test the attainment of science objectives in the cognitive domain, and a few are involved with the psychomotor and affective domains.

There is no significance in the order in which the techniques are presented, and it must not be assumed that these are the only techniques possible. It is strongly recommended that science teachers use a substantial variety of evaluation techniques so that the achievements of students may be assessed from different perspectives.

The following techniques range from objective to subjective. In objective evaluation, the students are limited to answering with a word, a phrase, a number, or a symbol. The questions are highly structured, and the types of answers are dictated by the questions. Students do not have to organize sentences and express them in their own style. Such objective techniques are generally “reliable” in the sense that different people who mark the answers will come up with very nearly the same evaluation.

In subjective evaluation, students have the opportunity not only to recall facts, concepts, and principles, but also to organize their thoughts, to integrate ideas, and to express them logically. Subjective questions must be stated clearly and accurately. The answers vary greatly from student to student, and value judgements must be made by the teacher. For this reason, subjective evaluation is less “reliable” than is objective evaluation. This can be overcome to some extent by teachers making it abundantly clear what expectations they have of their students.

Short answer

This technique consists of a question that is answered by a word, phrase, number, symbol, or formula; it often requires the process of recall. The following are a few examples:

- a) What is the name of the curved surface at the top of a liquid in a container? _____ (*meniscus*)
- b) What is energy defined as? _____
(*the ability to do work*)
- c) How many newtons does it require to support 2 kg at the earth's surface? _____ (20)
- d) What is the symbol for kilometres per hour? _____ (km/h)
- e) What is the formula that relates distance (d) and time (t) with speed (v)?
_____ ($v = d/t$)

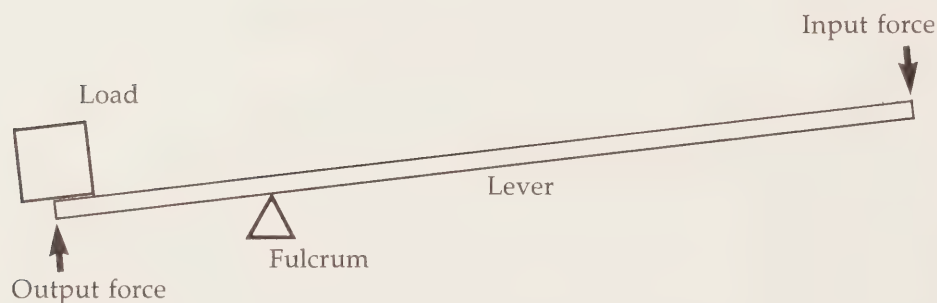
Completion

This kind of question is very similar to the last; both are objective in nature. The following are a few examples:

- a) Animals with backbones are classified as _____.
(vertebrates)
- b) The two colours, in order, between red and green in the spectrum are _____.
(orange and yellow)
- c) 1 ha = _____ m². (10 000)
- d) The correct spelling of "corrola" is _____.
(corolla)
- e) The three methods of heat transfer are called _____,
_____, and _____.
(conduction, convection, radiation)

Labelling

This exercise is really a form of completion. A diagram is given with parts to be named indicated by arrows or numbers. It is suggested that students not be asked to draw and label *complicated* diagrams, especially under the pressure of a time limit. Rather, teachers can give good direction by providing the necessary diagrams of complex apparatus, biological structures, models, or life cycles. Students should be encouraged, however, to use simple sketches and diagrams to illustrate parts of an answer or report. For example: Draw a labelled first-class lever (to scale) having a mechanical advantage of 3.



M.A. = 3

True-false selection

This kind of question is also objective and requires recall and recognition of such items as terms, facts, and concepts. For example:

State whether the following are true or false.

- a) Angiosperms are seed plants that develop flowers. (True)
- b) When iron is heated, its density increases. (False)
- c) Sirius is the name of a type of cloud. (False)

Multiple choice

This familiar testing device requires a selection of the best answer from an array of possibilities. For example:

The response of mimosa to touch is called: (a) metabolism, (b) irritability, (c) locomotion, (d) adaption, (e) predation.
Answer: (b)

Matching

This objective technique requires that students relate concepts with key words, examples, or units. For example:

Match the following physical quantities with their units:

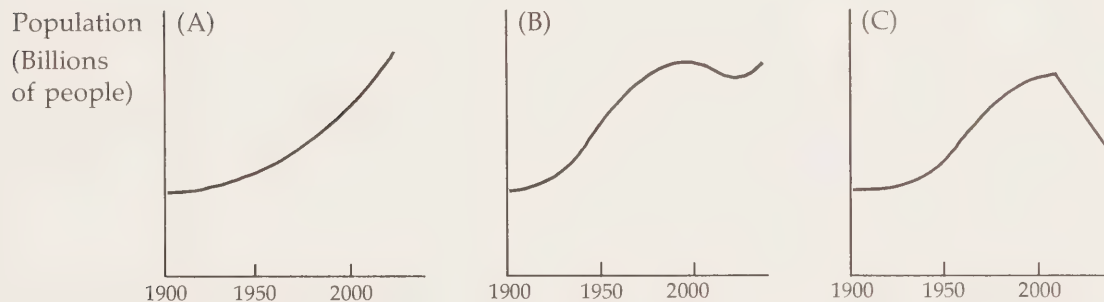
- | | |
|--------------|-----------------------------|
| 1) power | a) hertz |
| 2) force | b) kilogram per cubic metre |
| 3) energy | c) joule |
| 4) pressure | d) watt |
| 5) speed | e) kilogram |
| 6) frequency | f) metre per second |
| 7) mass | g) cubic metre |
| 8) volume | h) pascal |
| 9) density | i) newton |

(1d, 2i, 3c, 4h, 5f, 6a, 7e, 8g, 9b.)

Interpretive exercise

Interpretive test questions are generally objective and often involve multiple-choice questions. They are frequently based on a common set of data, terms, written material, tables, charts, graphs, maps, or diagrams. Such exercises can measure a variety of learning objectives, both simple and complex, including interpretations of laboratory experimentation. This technique can be used to evaluate processes of inquiry. (It may be subjective if students are required to write out their own interpretations.) Here are two examples:

- a) Which one of the following graphs supports the hypothesis that the population on the earth will likely reach a critical state?



Answer: (A)

- b) From the information in the following chart, which of the objects – A, B, C, or D – has the greatest density?

Object	Mass	Volume
A	2700 kg	1.0 m ³
B	2.7 g	1.0 cm ³
C	2500 g	1.0 L
D	2.8 kg	1.0 dm ³

Answer: (D)

Mathematical problem-solving

Problem-solving involving mathematical calculations can provide an effective evaluation technique. The following problem could be given to test understanding of the concept of speed. It is important to note that such a problem can be solved by several methods.

An antelope can run at 60 km/h and Tarzan can run at 20 km/h. The antelope and Tarzan start together at point A and run to point B which is 10 km away. How long will the antelope wait for Tarzan at point B?

Solution (a) (Statement method)

The antelope can run 60 km in 60 min; therefore, the antelope runs 10 km from A to B in 10 min. Tarzan can run 20 km in 60 min, and, therefore, runs the 10 km from A to B in 30 min.

Hence, the antelope arrives 20 min ahead of Tarzan.

Solution (b) (Formula method)

$$\begin{aligned} \text{Tarzan:} \quad v &= 20 \text{ km/h} \\ d &= 10 \text{ km} \\ t &= \frac{d}{v} = \frac{10 \text{ km}}{20 \text{ km/h}} = 0.5 \text{ h} = 30 \text{ min} \end{aligned}$$

$$\begin{aligned} \text{Antelope:} \quad v &= 60 \text{ km/h} \\ d &= 10 \text{ km} \\ t &= \frac{d}{v} = \frac{10 \text{ km}}{60 \text{ km/h}} = \frac{1 \text{ h}}{6} = 10 \text{ min} \end{aligned}$$

Antelope waits 20 min

Notes and reports

The writing of notes and reports is a vital part of most science courses. Students' notebooks can contain the essence of what they are expected to learn and understand, and the evaluation of their notebooks can be of great benefit to them. The teacher should make clear what kinds of notes are considered desirable. In general, notes and reports should be neat and well organized, with distinct and sequential headings. They should include lists and summaries that are important to the student. Diagrams and graphs should be clear and straightforward. Attention should be given to correct spelling and grammatical structure. Both full-sentence and point-form are acceptable. Students should take pride in their note-taking, bearing in mind that the work of a scientist, whether handwritten or typeset, is of little use to others unless it is coherent and well organized.

Projects

Student projects may take the form of a written paper or a working model. Such projects can be evaluated using criteria such as those suggested by the following questions:

- Does the project have a purpose: the explanation of a phenomenon, the solution of a problem, or the presentation of a hypothesis?
- Is the project well organized, developed logically, and clearly presented?
- Are the given data relevant and reliable?
- Are the processing and display of data clear?
- Are variables properly controlled in the project?
- Is the conclusion or end result properly substantiated?

Other criteria can be selected from those developed for science fair projects by the Youth Science Foundation in Ottawa. Any criteria established should be clearly understood by the students.

Restricted-response essay

Through this technique, students are required to apply data, list observations, describe techniques, or give explanations in a short essay form. Certain restrictions, such as the number of points to be given and the time limit, should be indicated to guide the students in their response. For example: In 10 min, list four characteristics of living organisms and suggest a demonstration and its expected result to illustrate each characteristic.

Extended-response essay

If an extended-response essay is chosen as a method of evaluation, the student's response can reflect a depth of understanding, a freedom of expression, originality, and critical thinking. The essay may be written at home and perhaps marked jointly by the science and English teachers. Students need ample warning of the time permitted and some stipulation regarding overall length. For example: In not more than 600 words, write an essay entitled, "Balance in the Biosphere". Indicate a number of human-induced changes that have affected the biosphere. Describe some of the harmful effects of these changes and suggest how you could become involved in helping to rectify the damage.

Qualitative experiment

A qualitative experiment can be profitably used to evaluate manipulative and behavioural performance. During the experiment, the teacher can observe manipulative skills, experimental design, safety precautions, efficient use of equipment, and general co-operation and conduct. Perhaps only one aspect of an experiment need be evaluated at a time, for example, the number of characteristics or changes that the students observe in the experiment. Here are two examples:

- a) Observe and describe everything that occurs when half an Alka-Seltzer tablet is dropped into cold water and the other half is dropped into warm water.
- b) Prepare and test some oxygen.

Quantitative experiment

A quantitative experiment is similar to a qualitative experiment, but has the additional aspects introduced by counting or measurement processes. It, therefore, has an extra dimension by which student performance may be evaluated. The following are some typical examples:

- a) Investigate the numerical growth of a yeast population.
- b) Find the percentage of water in a hydrate.
- c) Measure the dimensions of a specimen that is mounted on a microscope slide.
- d) Determine the density of a rock.

Bell-ringer test

Experimental exercises can be set up at sequential stations around a room for this type of test. The problem to be solved or the activity to be performed is stated on a card at each station. At suitable intervals, the teacher indicates, by ringing a bell, that students are to move on to the next station. Here are two examples:

- a) Suitable rocks, minerals, and fossils, with the required investigative equipment, are placed at each station with exercises to be completed at the conclusion of the study of Rocks and Minerals (Unit E16).

- b) A good number of measurement exercises may lend themselves to this type of test: the cost of a piece of wire at 65¢/m (students measure the wire); the cost of floor tiling at \$4.50/m²; the estimated temperature of an electric heating pad; the speed of a toy train; the estimated mass of an apple and a watermelon; the volumes of several containers – some to be measured and some estimated; the cost of a trip at 13¢/km, based on an Ontario map; the density of a liquid; the period of a pendulum.

Puzzles

Many students like solving puzzles. They can be used throughout the school year to promote problem-solving. This kind of student evaluation should not be forced; from it, the teacher will gain an impression of those students who are interested and ingenious. Written puzzles may appear on the chalkboard and manipulative puzzles can be displayed for use in certain areas of the room. Certain games requiring logical thinking may be used by responsible students before and after school. Here are two examples:

- a) Find three errors in the following sentence. "Their are three mistakes in this sentence." (*Two spelling mistakes plus an incorrect count*)
- b) Mary leaves point A when Teresa leaves B and they cycle towards one another. A fly also leaves point A at the same time and flies towards Teresa. When the fly reaches her, it flies back to Mary, and continues to fly back and forth between the two girls until all three meet. AB = 60 km. Mary cycles at 14 km/h, Teresa cycles at 10 km/h, and the fly flies at 20 km/h. How far does the fly fly? (50 km).

Critical thinking

Particular attention should be given to the evaluation of critical thinking and reasoning skills in a science course. Questions can be based on a factual or fictitious statement and should be designed to encourage students to reason for themselves. They should be able to reason from cause to effect, to draw inferences, to apply previous knowledge, to create suppositions, to distinguish fact from fiction or opinion, and to come to conditional conclusions. Here are two examples:

- a) Suppose that the average temperature of Ontario (use 7°C) started now to drop at the rate of 1°C/a (one degree Celsius per annum), what do you think would happen during the next half century?
- b) "The use of penicillin produces bacteria that are resistant to penicillin." Answer the following basing your replies on this statement:
- What does this statement mean?
 - What are the main consequences of this fact?
 - What is the logical conclusion?
 - How does this fact affect you?
 - How does it or will it affect your community?

Student questions

Working scientists require the ability to form perceptive questions. Thus, the questions that students ask may serve as a good evaluative technique. The point here is to see if the students can frame good questions. In this case, it is more important for them to be able to ask questions than to answer them. The questions asked by students will require subjective evaluation. It is not always easy to decide whether a given question is a good one or not. Student questions may be evaluated on the basis of depth of understanding, inventiveness, clarity, relevance, applicability, and similar characteristics. For example:

- a) The students are given an object with which they are unfamiliar and asked to list a dozen sensible questions that a person might ask about the object.
- b) After studying observation through the use of all five senses, students might ask questions such as the following:
 - Are there only five senses?
 - Which sense does a blindfolded person use when balancing on a narrow rail?
 - Why do people see mirages?
 - Can a person with acute hearing be deceived by some sounds?
 - Can a person be deceived by taste?
 - Why do our eyes see yellow when we look at a banana?
 - Why does water feel wet?
 - How would a blind person describe a rose?

Processes

Evaluating the development of intellectual processes in scientific work is difficult but important. It is useful to observe students during investigations and to assess their progress against a checklist. Such lists vary from teacher to teacher. The following one is given for consideration only:

- observing;
- classifying;
- comparing, contrasting;
- listing or placing in order;
- understanding number relations – calculating, graphing;
- estimating and measuring;
- predicting;
- inferring;
- communicating – presenting, describing, explaining;
- making operational definitions;
- identifying problems;
- formulating hypotheses;
- designing experiments and tests;
- controlling and manipulating variables;
- organizing and processing data;
- interpreting data;
- evaluating conclusions;
- substantiating hypotheses;
- establishing interrelationships between concepts;
- forming generalizations;
- creating and using models and theories;
- identifying examples and making applications.

Attitudes

Beyond the attainment of scientific understanding, the development of positive attitudes is an essential part of the science program. This may be evaluated by the use of an observational checklist. Such a list could be shared with the students, who, in turn, might enrich it with ideas of their own. The following are attitudinal attributes that may be listed as desirable:

- manifests curiosity;
- shows initiative;
- is honest;
- is co-operative – receptive and willing to share;
- has confidence and pride in work well done;
- has respect for learning;

- is diligent and enjoys work;
- is open to techniques of inquiry;
- treats equipment with care;
- has consideration for plants and animals;
- adopts safety procedures;
- seeks to use energy wisely;
- is concerned about pollution and abuse of the environment;
- is willing to accept responsibility;
- seeks to apply learning to real-life situations;
- shows a concern towards the societal implications of science.

Relating Science Topics to Alternative Sets of Objectives

Differing Curriculum Emphases

The same science content can be oriented towards the attainment of several different kinds of objectives. In science education, it is common to think of objectives in such categories as knowledge, skills, and attitudes, or in such “domains” as cognitive, affective, and psychomotor. Another kind of categorization recognizes different *emphases* that teachers, schools, or school boards may choose as being appropriate to the development of local curricula.

For example, one emphasis might be to have students master the subject matter and, *in addition*, to develop the characteristics of thought commonly referred to as “scientific literacy”. This emphasis would give rise to one set of objectives. A different set of objectives would be derived if the choice were made to have students master the subject matter and, *in addition*, to come to understand the relationships among science, technology, and personal and political decision-making. A third set of objectives would emerge if it were decided that the subject matter should be taught in a way specifically designed to develop the students’ skills at using scientific processes. A fourth curriculum emphasis might shape the teaching of the subject matter so that the structure of the discipline of science is revealed.

These are only four illustrative examples of many possible curriculum emphases. Furthermore, the entire program for Grades 7 to 10 need not be oriented around a single curriculum emphasis — one of these four or any other. It is even possible that *all* of these emphases might be adopted. In this case, mastery of the subject matter throughout the four years of the Intermediate Division would be achieved, yet the curriculum emphasis might change every year, or perhaps every two or three months. (It is doubtful that the objectives inherent in a single emphasis could be attained if they are not stressed for at least the period of time occupied by the traditional unit of study.)

“Hybrids” are also possible, of course. The four sample curriculum emphases listed above are not mutually exclusive. But each is relatively coherent, so that hybridization would have to be undertaken with some care. Let us first examine each of the four sample orientations in more detail, and, subsequently, consider how the same bit of subject matter can be oriented in four different ways.

- a) *The “scientific literacy” emphasis.* One of the clearest definitions of the concept of “scientific literacy” is that offered by Robert Karplus, who has made systematic and extensive use of the concept both in his writings and in curriculum development.

In other words, to be able to use information obtained by others, to benefit from the reading of textbooks and other references, the individual must have a conceptual structure and a means of communication that enables him to interpret the information as though he had obtained it himself. I shall call this functional understanding of science concepts “scientific literacy”.¹

In learning the core subject matter, then, a student is intended to experience knowledge in highly personal terms – as information gathered by a person, conceptualized by a person, and explained by a person. Ultimately, the student would come to see himself or herself as someone who does similar kinds of activities and, therefore, who operates conceptually and intellectually on the basis of his/her own experiences.

- b) *The “science, technology, and decisions” emphasis.* This curriculum emphasis is concerned with the relationships among scientific knowledge, technology, and personal and political decision-making. Some approaches to environmental studies are oriented in this way, and integration with social studies is readily achieved if a decision is taken to orient the science curriculum according to this emphasis.

In addition to mastering the subject matter, the student must come to terms with the place of science in contemporary human affairs. For example, scientific knowledge has a significant but limited role to play in the discussions related to the Mackenzie Valley Pipeline. Thus, a very important aspect of science can be presented: science results in the accumulation of knowledge and not in a series of prescriptions for action. The Aristotelian distinction between matters theoretic (resulting in warranted knowledge) and matters practical (resulting in defensible decisions) is important for understanding this curriculum emphasis.²

- c) *The “scientific processes” emphasis.* This curriculum emphasis is based on the analysis of scientific work into a list of related but different kinds of intellectual performances. Probably the best known of such analyses is that of Robert Gagné. His analysis has been embodied in a coherent set of teaching materials that reflect this curriculum emphasis for the elementary school. Gagné writes as follows:

The most striking characteristic of these materials is that they are intended to teach children the *processes* of science rather than what may be called science content. That is, they are directed toward developing fundamental skills required in scientific activities. The performances in which these skills are applied involve objects and events of the natural world; the children do, therefore, acquire information from various sciences as they proceed. The goal, however, is not an accumulation of knowledge about any particular domain, such as physics, biology, or chemistry, but competence in the use of processes that are basic to all science.³

¹ Robert Karplus, “The Science Curriculum Improvement Study”, *Journal of Research in Science Teaching* 2, no. 4 (1964), pp. 293-303. The definition appears on p. 296.

² A clear explanation of the distinction and its implications for science studies is provided in Joseph J. Schwab, “Decision and Choice: The Coming Duty of Science Teaching”, *Journal of Research in Science Teaching* 11, no. 4 (1974), pp. 309-17.

³ Robert M. Gagné, “Elementary Science: A New Scheme of Instruction”, *Science* 151 (January 7, 1966), pp. 49-53. See also his book *The Conditions of Learning* (New York: Holt, Rinehart and Winston, 1966).

According to Gagné, eight “basic” processes and six further “integrated” processes together characterize scientific work. The “basic” processes are observation, classification, communication, number relations, measurement, space/time relations, prediction, and inference. The “integrated” processes are formulating hypotheses, making operational definitions, controlling and manipulating variables, conducting experiments, formulating models, and interpreting data.

Thus, teaching that reflected this curriculum emphasis would have students master the subject matter, and in addition, practise and develop skills in a specified collection of scientific processes. Despite Gagné’s comment that the particular materials he describes do not pay specific attention to the mastery of content, there is nothing inherently contradictory about an orientation that stresses both content and process.

- d) *The “structure of science” emphasis.* Many science teachers sequence their teaching according to overarching conceptual organizers, such as “conceptual schemes of science”. This approach suggests one kind of structure of science: a perspective for individual concepts and ideas is sought in a larger, comprehensive framework.

Another sense of the structure of science – the sense discussed here – is derived from the intellectual way in which science works. In this second sense, the structure of science draws heavily from the philosophy of science. Thus, in addition to mastering the subject matter, students exposed to this curriculum emphasis reflect on such matters as the interplay of evidence and explanation; the changing and self-correcting nature of scientific knowledge; the difference between mental processes involved in formulating such concepts as “mammal” or “metal” (category names) on the one hand and “gene” or “electron” (postulated entities) on the other; the conceptual role played by models and analogies; the influence of an investigator’s perspective on the kind of explanation developed; and similar philosophical concerns. The work of Joseph Schwab is helpful in understanding this emphasis.⁴

Practical Example I: From Physical Science

Having considered the four sample curriculum emphases, let us now see how the same bit of subject matter might be treated in a manner consistent with each emphasis. The topic used comes from Properties of Matter (Unit E6), Topic E6.5: Biological, chemical and physical properties. One core-content objective for all four emphases requires that the student know what “chemically reactive” means: that it refers to reactions, rather than individual substances only, and that it is a way of expressing observable differences in the vigour of different reactions. Thus, the core-content objective might be stated as follows: “The student knows that the concept ‘chemically reactive’ expresses the relative vigour with which reactions proceed.”

⁴ See, for example, “The Structure of the Natural Sciences”, in G.W. Ford and Lawrence Pugno (eds.), *The Structure of the Disciplines and the Curriculum* (Chicago: Rand McNally, 1964), pp. 31-49; and “The Teaching of Science as Enquiry”, in Joseph J. Schwab and Paul F. Brandwein, *The Teaching of Science* (Cambridge, Mass.: Harvard University Press, 1964), pp. 3-103.

Now let us turn to the differing objectives (depending on the teacher's preferred emphasis) that might be coupled with this core-content objective, when the subject matter is used as a vehicle for the attainment of objectives that are beyond the straightforward learning of scientific facts, principles and explanations. The following suggestions are offered for illustrative purposes only.

- a) *The "scientific literacy" emphasis.* The key point about this emphasis is that *the student eventually comes to understand knowledge as if he/she had personally developed it.* Thus, science teaching consistent with this emphasis frequently has the student getting his/her own information – in an appropriately supervised situation – as well as striving for an understanding of why certain steps are taken in developing that information. The student must see, and indeed "feel", the need for a new concept.

Suppose the teacher began development of the concept "chemically reactive" by dropping a small pebble into a beaker of water and then asking the students whether they observe a chemical reaction. At this point, discussion would have to include the basis for saying that such a reaction had or had not occurred – the familiar criteria of temperature change, emission of light, chemical changes in the reactants, and so on. While the class might comment on the appearance of some bubbles (depending on the porosity of the pebble), it is doubtful that many students would insist that a reaction was occurring.

Next, the teacher drops a piece of limestone – about the size of the pebble – into a beaker of dilute hydrochloric acid and again asks whether a chemical reaction is taking place. Evidence is sought and indicators applied. The teacher then carefully drops a small pellet of sodium in a beaker of water and again asks whether a chemical reaction is taking place. More evidence is sought and other indicators applied. The picture begins to emerge: some reactions are more vigorous than others. The students see the need for a concept of chemical reactivity to express the difference in vigour. This need is discussed, and the concept is extended to other situations in which differences in the vigour of reactions might have been observed. The students must assess whether the concept is helpful in articulating an observable difference among reactions.

Teaching that takes students beyond the development of a concept to a discussion of its usefulness or purpose for them as individuals is said to be aimed at the development of scientific literacy. The following are sample objectives that express this emphasis:

- i) *The student realizes that the concept "chemical reactivity" was created for the purpose of making qualitative and observable differences systematic.*
- ii) *The student appreciates that this particular concept is useful only if it serves its intended purpose.*

Both of those objectives are *cognitive*, in one sense, since both deal with matters the student comes to understand. Yet both are also *affective*: they implicitly express value statements about the use of the mind in coming to grips with natural phenomena. The following is a sample *skill* objective to which this emphasis contributes:

- iii) *The student is able to assess whether a concept serves its intended purpose.*

- b) *The “science, technology, and decisions” emphasis.* The core-content objective still holds: the student is to know the *meaning* of the concept “chemical reactivity”. Beyond that, what might a teacher who chose this curriculum emphasis do in the classroom to illuminate the relationships among scientific knowledge, technology, and personal and political decision-making?

Science and technology are quite different, of course – science aims at knowledge, while technology aims at bettering our lot in everyday affairs. Personal and political decisions can take into consideration the knowledge and/or findings of science on technological grounds alone. They always take into account human desires and wants, as well as estimates of cost versus benefit (both human and material).

Imagine a teacher introducing the concept of chemical reactivity as before. The pebble is dropped into water, the limestone into dilute hydrochloric acid, and the sodium pellet into water. The teacher and class quickly agree that the observations indicate (1) no reaction, (2) slow reaction, (3) more vigorous reaction. Without further ado, the teacher announces that “chemical reactivity” is a phrase used to encapsulate the differences: no visible reactivity for (1), some reactivity for (2), and still greater reactivity for (3). When the students make that connection, the core-content objective has been attained, and the concept is now secure.

Next, the teacher and class consider reactions between metals and the components of the natural environment (for example, water vapour, oxygen, carbon dioxide). They examine the relative chemical reactivity of those components and such metals as lead and iron on the one hand, and potassium and sodium on the other. The approximate historical dates of the first isolation of elemental lead, iron, potassium, and sodium are now presented and compared. Why is it that metals of low reactivity with components of the natural environment – metals such as iron and lead (and, indeed, copper, silver, and gold) – were isolated and used in antiquity, while metals of high reactivity with environmental components – metals such as potassium and sodium (as well as magnesium, aluminum, and others) – have been isolated and used only more recently? A fascinating relationship between technology and science begins to come clear. Human ingenuity being what it is, people used metals that they found in the “natural state” (those exhibiting low-reactivity reactions), but were totally unaware that certain materials that they could observe were actually compounds of other metals – in the form of oxides, chlorides, and the like. Once the scientific *knowledge* about decomposing oxides, chlorides, and so on (by controlled application of heat or electricity) was available, the isolated metals could be exploited for technological purposes. Prior to this, who could have looked at a piece of limestone and suspected that it “contained” calcium or at a piece of salt and suspected that it “contained” sodium?

One aspect of the relationship between science and technology has begun to emerge, then. Consistent with this, some objectives for this curriculum emphasis for teaching about chemical reactivity could be stated as follows:

- i) *The student understands that science differs from technology as knowledge-seeking differs from practical problem-solving.*
- ii) *The student knows that technological know-how can suggest avenues of scientific inquiry, and, similarly, that scientific knowledge can open new possibilities for technological exploitation of the natural world.*

A further aspect of this curriculum emphasis is more complicated: the relationship among science, technology, and decision-making. Suppose the teacher were to ask the class (in a simulation exercise) to role-play a town council faced with a decision on whether to use salt or sand on snowy roads in the winter. What role does knowledge play in the deliberations? Automobile bodies are composed largely of a metal (iron) which is only moderately reactive with water; but the salt in the water drastically increases that reactivity. (This is a good place to plan and conduct an experiment.) Some members of the council might say that the answer is obvious – high reactivity causes extensive body damage; therefore, no salt. Use sand instead. After all, we don't want to have to replace our cars every two years! Others might note that salt does a more efficient job, because it can't be ploughed under by traffic. After all, people *do* have to get to work to earn a living!

In the simulation, students are obliged to take positions and to represent values, as is the case in real-life town-council deliberations. The important, but nevertheless limited, role of scientific knowledge in decision-making is, thus, exposed, discussed, and clarified.

Some further objectives towards which a teacher using this emphasis would be working can be stated as follows:

- iii) *The student realizes that practical decisions cannot be deduced directly from scientific knowledge, yet recognizes the role played by such knowledge.*
- iv) *The student recognizes the legitimate role of human desires and values in arriving at decisions concerning practical matters.*
- c) *The "scientific processes" emphasis.* As in the previous two emphases, the core-content objective is given: students are to understand what is meant by the concept "chemical reactivity". The essential feature of a curriculum emphasis based on scientific processes is that the teacher capitalizes on the subject matter to have students practise, and develop their skill in the performance of, specified intellectual processes: observing, classifying, inferring, measuring, designing experiments, and so on. How might this happen in the classroom?

Imagine the teacher developing the concept of chemical reactivity in the manner specified in the two previous examples. What intellectual performances are required of the students? *Observation*, surely, for they must report whether or not there is evidence of a reaction. *Measurement* of a sort is demanded – although it is a qualitative ("more than" or "less than") ordering that is being used.

Suppose that the teacher wishes to have students practise other processes. The following statement can be placed on the chalkboard: "The reaction of limestone and dilute hydrochloric acid shows less chemical reactivity than the reaction between sodium and water." The teacher then asks the students whether a larger piece of limestone might show a more vigorous reaction, thus possibly changing the

conclusion reached earlier. If the students do not suggest other variables, the teacher prompts: “What about the concentration of the acid?” or “Would the amount of water into which the sodium pellet was dropped make a difference?” or “Should the sodium and limestone have the same mass?” (Obviously, appropriate regard for safety is important here!) The pupils *formulate hypotheses* and *design experiments* to test the effects of the variables, and the teacher capitalizes on the opportunity to assist in the refinement of those skills by asking such questions as: “And what would that tell us?”, or “How does that suggestion build on what Mary just said?”

A sample objective that captures the spirit of this emphasis on scientific processes might be stated, then, as follows:

The student formulates hypotheses and designs experiments to test the effects of three variables on the observed vigour of two chemical reactions.

- d) *The “structure of science” emphasis.* While a curriculum emphasis on scientific processes concentrates on having students *develop performance skills*, an emphasis on the structure of science focuses on *why* those performances are important. Thus, consider again our teacher placing the tentative conclusion on the chalkboard: “The reaction of limestone and dilute hydrochloric acid shows less chemical reactivity than the reaction between sodium and water.” The teacher asks the students how much faith they have in the statement, what is doubtful about it, and what there is to be uncertain about. Teacher and class proceed to catalogue areas of uncertainty and to design experiments to eliminate or reduce their doubts. The teacher frequently reminds the class that each experiment has a specific purpose, thus relating the “performance” aspects of science to knowledge claims.

In the end, there will always be some doubt about the conclusion built by teacher and class. Yet, many interesting variables will likely emerge in the discussion. For example, would the reactivity of limestone and dilute hydrochloric acid increase if the limestone were pulverized, thereby vastly increasing its surface area? Or how many different concentrates of “dilute” acid are enough?

Sample objectives summarizing this aspect of a curriculum emphasis on the structure of science as a discipline might be worded as follows:

- i) *The student understands that scientific statements always contain an element of doubt.*
- ii) *The student knows that experiments in science are undertaken in order to develop, refine, and assess knowledge claims.*

Practical Example II: From Biological Science

For our second practical example, consider the idea of spontaneous generation. Such a topic could arise from a locally designed unit, perhaps in Grade 9 or 10. Again, the content objective for all four sample curriculum emphases would be the same: in this case, the meaning and discredited status of spontaneous generation as an explanation for the production of life. The content objective could be stated in three parts.

- i) *The student knows that spontaneous generation, or abiogenesis, refers to a hypothesis asserting that living creatures can originate from non-living material.*
- ii) *The student knows that biogenesis refers to a hypothesis asserting that living creatures originate only from other living creatures.*
- iii) *the student knows that biogenesis is the hypothesis accepted by the majority of biological scientists today.*

The content objective can readily be realized if students understand the significance of Pasteur's experiments with infusions of yeast. Let us consider them at some length.

In Pasteur's time, some biologists believed that spontaneous generation could occur, but only in the presence of air. Pasteur, however, was convinced that the air contained spores of micro-organisms. The debate arose because a series of experiments with hay infusions had shown that when a boiled infusion was sealed from the air, it did not become cloudy. On the other hand, boiled infusions exposed to air became cloudy with micro-organisms after a few days. Biogenesisists like Pasteur explained the cloudiness by asserting that air was a contaminant. Abiogenesisists explained the *lack* of cloudiness by asserting that air was necessary for spontaneous generation to occur. Pasteur's contribution to the debate was to cast doubt on the generality of the results of such experiments. He boiled and sealed a large number of yeast infusions. When opened to admit air and then sealed again, some infusions became cloudy and could be seen to be teeming with live micro-organisms; others remained clear and free of micro-organisms. Moreover, the point at which air was admitted to the sealed infusions seemed to make a difference.

The teacher could demonstrate vividly the nature of the observations which biogenesisists and abiogenesisists of Pasteur's time were debating. The following suggestion is illustrative. A hay infusion (chopped hay in water) is boiled for about ten minutes and then divided equally between two sterilized flasks – one to be sealed, the other to be left open to the air. (The mixture should nearly fill each flask.) After a few days, the infusion in the open flask becomes cloudy; a drop from it placed under the microscope shows the presence of micro-organisms. If the other flask has been properly sealed, the infusion in it should remain clear. Once opened to the air, however, the infusion in the second flask behaves like that in the first flask. Pasteur's contribution in throwing doubt on the idea of spontaneous generation can be demonstrated with equal ease: yeast infusions do not behave in the same way as hay infusions – at least, not consistently. Thus, the content objective can be achieved if teacher and students focus on the influence of Pasteur's work. This could be done by discussion alone, or through demonstration and discussion. But now let us look at the differing objectives that can be attained by using the subject matter as a vehicle for the four sample curriculum emphases; again, the suggestions are illustrative only.

- a) *The "scientific literacy" emphasis.* This curriculum emphasis attempts to have students reach the point where they understand knowledge as if they had developed it themselves. In order that the subject matter of spontaneous generation be shaped to accomplish the aims of this curriculum emphasis, students must become *personally involved* in the biogenesis/abiogenesis debate through evidence that they interpret themselves. That is, they need to "feel" the debate as a plausible, believable one. (It lasted for some three centuries, after all.) How might this involvement be promoted in the classroom?

The students must first be encouraged to drop their prejudices in favour of biogenesis in order to assess the evidence and arguments that arise in the course of their work. Spallanzani's work, which preceded Pasteur's, would probably be a good starting point. If broth is boiled and its container quickly sealed (using, for example, a test tube, "pulled out" in the centre over the hot flame of a Bunsen burner to make a sealed ampoule), the broth remains clear. A control that *is* heated but *not* sealed and another control that *is not* heated but *is* sealed both develop cloudiness after a few days. (For best results, do three or four of each kind.) Micro-organisms can be seen, if the contents of the two controls are examined under the microscope.

It is of central importance for this curriculum emphasis that the students actually make these observations – whether or not they prepare the materials themselves. (That is, the teacher could demonstrate, but the students must see the evidence.) The teacher then asks how the students account for the presence of micro-organisms in the unheated, sealed containers *and* the heated, unsealed containers, but *not* in the heated, sealed containers. Some students may say that heating killed the micro-organisms in the latter. If so, those in the heated, unsealed container must have generated spontaneously. Others might say that air contaminates the broth with spores in the heated, unsealed container. If so, the micro-organisms in the unheated, sealed container must have generated spontaneously.

Thus, the search for a *single* causal factor to account for the evidence can lead some students to champion the explanation of spontaneous generation. Now the debate has become credible for them. Those who wish to argue in favour of biogenesis would say that there are *two* sources of micro-organisms: broth and air. Thus, the heating kills micro-organisms present in the broth, but the air is full of spores. Hence, the heated, unsealed control is contaminated by spores, while the unheated, sealed control is still full of indigenous micro-organisms anyway. The abiogenesisists can then reply that air was not driven out of the unheated, sealed test tube; thus, air is present in both cases where micro-organisms appear, but absent where they do not; therefore, spontaneous generation occurs, but only in the presence of air. And there the debate rested until Pasteur's work shed more light on the subject.

Once the students are involved in the debate, Pasteur's work can be introduced and treated in the same manner as Spallanzani's work. The content objectives are thus attained, and, in addition, the objectives consistent with a curriculum emphasis on scientific literacy are satisfied. An example of the latter might be expressed as follows: *The student recognizes that his/her initial loyalty to an explanation can influence his/her interpretation of evidence.*

- b) *The “science, technology, and decisions” emphasis.* Beyond the content objective – knowing the meaning and discredited status of spontaneous generation – there are numerous possibilities for shaping this bit of subject matter to illustrate the differences among science, technology, and decisions. By discrediting spontaneous generation as an explanation for the development of life, Pasteur and others who preceded and followed him forced us to pay attention to conditions of sterility and to external *sources* of “infection”.

The teacher might focus on the technological problems involved in preserving milk for distribution and consumption quite some time after it leaves the farm. Virtually every student will have smelled soured milk, and many students will know what happens to milk when it is boiled. Scientific knowledge lets us predict how long the residual bacteria “infecting” milk will stay dormant when the milk is heated to various temperatures for various lengths of time, assuming it is then kept in a refrigerator. (This might be an interesting laboratory experiment.) Generally speaking, the higher the temperature to which it is heated, the longer the milk will keep without spoiling. Yet there is a point at which the milk changes dramatically. So how does one arrive at the appropriate temperature to make the milk “safe enough” in the pasteurizing process, yet not destroy its taste and other important qualities?

A decision is needed, and the decision is not a scientific one (as, for example, the decision about whether biogenesis or abiogenesis is the better explanation for the development of life). The range of temperatures is narrow, and one health department might be fairly conservative, asking for the highest possible temperature, while another might be less stringent, thereby saving money for the processor and eventually the consumer. Dairy farmers have an interest in this decision as well, as do milk-processing firms: their livelihood depends on the delivery of goods to the consumer with a minimum of spoilage and a maximum of taste and other desirable qualities.

The teacher could arrange a debate, a simulation, an essay contest, or a straightforward discussion in order for students to see the difference between knowledge-seeking and decision-making in this context. To highlight the difference between science and technology, field trips to a microbiology lab and to a milk-processing plant could be undertaken with that specific purpose in mind.

Sample objectives for this curriculum emphasis could be stated, as before, in the following manner:

- i) *The student understands that practical decisions cannot be arrived at by simple deduction from scientific knowledge, yet recognizes the role played by such knowledge.*
 - ii) *The student recognizes the legitimate role of human desires and values in arriving at decisions concerning practical matters.*
 - iii) *The student understands how scientific knowledge can be used as a basis for bettering our lot in everyday affairs.*
- c) *The “scientific processes” emphasis.* Again the content objective is the same: students are to understand the meaning and discredited status of spontaneous generation. In a curriculum emphasis on scientific processes, the subject matter is used as a vehicle for having students practise selected intellectual processes. How might that be done in this case?

In their discussion of Pasteur's work related to the content objective, students make use of several scientific processes. *Observation* is necessary, of course, in examining and comparing hay infusions and yeast infusions; students *infer*, as Pasteur and others did, that a turbid, cloudy infusion contains micro-organisms. They are, therefore, practising these two processes. (It is helpful if the teacher points out the inferences being made.) What of other possible processes in the context of this subject matter?

Suppose it was decided that students should practise controlling and manipulating variables. (Inevitably, this will also involve the students in practising experimental design.) The teacher asks the students to identify all the possible variables in Pasteur's experiments: the concentration of yeast, the amount of nutrient (sugar), the kind of sugar, the strain of yeast, the temperature to which the mixture is heated, the time for which the highest temperature is maintained, the time that elapses before sealing, and so on. This gives them practice in *identifying* variables, and, indeed, the teacher might have to prompt the students somewhat. Next, they are asked to design and carry out an experiment to test the effects of concentrating the yeast. This will require that they control all variables except the concentration of yeast and that they decide on how to manipulate the latter and on how to predict and observe the results.

From this illustrative example of some of the scientific processes that students can practise, we could state objectives consistent with a curriculum emphasis on scientific processes as follows:

- i) *The student identifies all the independent variables in a complex experimental arrangement.*
- ii) *The student successfully controls all independent variables save one, and manipulates that one successfully.*
- d) *The "structure of science" emphasis.* It will be recalled that a curriculum emphasis on the structure of science concentrates on the way science works intellectually – the *purposes* behind experiments, the interplay of evidence and explanation, and so on. In the present context, let us assume that the students have achieved the content objective on the basis of understanding the significance of Pasteur's work. The teacher now raises the point that Pasteur used *yeast* infusions, while the chief French protagonist for abiogenesis of the time, Pouchet, had used *hay* infusions. Pouchet *always* found that his infusions became cloudy when air was admitted, even after careful boiling and sealing or when air was admitted from a variety of locations. Pasteur's infusions became cloudy with micro-organisms only *sometimes*, under the same conditions. The students are now invited to comment on the possible significance of the fact that one experimenter used infusions of hay, while the other used yeast. (Note that both men were highly respected experimental scientists.)

The students might also wish to question the assumption – made by both experimenters – that the temperature of boiling water would be sufficient to kill all micro-organisms in their samples.

By exploring these areas of doubt with the students, the teacher could pave the way for a discussion of what thinking and experimenting would be needed to "tidy up" the biogenesis/ abiogenesis debate, as it stood in the wake of Pasteur's work.

In addition to exploring the effect on the debate of the two points mentioned above, the teacher might also introduce the much-earlier work of Francesco Redi on spontaneous generation in micro-organisms. A number of investigators from the time of Redi until the time of Pouchet and Pasteur contributed to the controversy over abiogenesis. By exploring the ways in which each investigator's work contributed to the accumulating evidence and knowledge structure, the students come to see the cumulative and self-correcting nature of science.

Sample objectives that express the aims of this curriculum emphasis in the context of the subject matter dealing with spontaneous generation might be stated as follows:

- i) *The student understands that biogenesis was still a doubtful hypothesis, even after Pasteur's work, and understands why it was still doubtful.*
- ii) *The student realizes that a prejudice in favour of one of two conflicting ideas can influence the interpretation of evidence.*
- iii) *The student understands how the story of biogenesis illustrates that science is a cumulative and self-correcting enterprise.*

Some Concluding Remarks

The four sample curriculum emphases detailed and illustrated above do not exhaust the possibilities, yet they are sufficiently varied to demonstrate the flexibility available to curriculum developers dealing with the science program for Grades 7 to 10. In each case, the content objective is the same, yet differing objectives can be combined with it. It is informative simply to list the sample objectives provided, as shown in the charts on the next two pages, in order to compare the different outcomes that are consistent with the four sample curriculum emphases discussed here.

Finally, it should be noted that objectives have been expressed as intended "mental states" of the learner, rather than in behavioural terms. This is deliberate. Behavioural objectives would subsequently be stated (as part of the curriculum development process) as observable indicators of achievement of the statements of intent.

Summary of Sample Objectives for a Range of Curriculum Emphases

1. Physical Science Example

Content objective	Curriculum emphases	Objective(s)
The student knows that the concept “chemically reactive” expresses the relative vigour with which reactions proceed.	<i>Scientific literacy</i>	i) The student realizes that the concept “chemical reactivity” was created for the purpose of making qualitative and observable differences systematic. ii) The student appreciates that this particular concept is useful only if it serves its intended purpose. iii) The student is able to assess whether a concept serves its intended purpose.
	<i>Science, technology, and decisions</i>	i) The student understands that science differs from technology as knowledge-seeking differs from practical problem-solving. ii) The student knows that technological know-how can suggest avenues of scientific inquiry, and, similarly, that scientific knowledge can open new possibilities for technological exploitation of the natural world. iii) The student realizes that practical decisions cannot be deduced directly from scientific knowledge, yet recognizes the role played by such knowledge. iv) The student recognizes the legitimate role of human desires and values in arriving at decisions concerning practical matters.
	<i>Scientific processes</i>	i) The student formulates hypotheses and designs experiments to test the effects of three variables on the observed vigour of two chemical reactions.
	<i>Structure of science</i>	i) The student understands that scientific statements always contain an element of doubt. ii) The student knows that experiments in science are undertaken in order to develop, refine, and assess knowledge claims.

2. Biological Science Example

Content objective	Curriculum emphases	Objectives
i) The student knows that spontaneous generation, or abiogenesis, refers to a hypothesis asserting that living creatures can originate from non-living material.	Scientific literacy	i) The student recognizes that his/her initial loyalty to an explanation can influence his/her interpretation of evidence.
	Science, technology, and decisions	i) The student understands that practical decisions cannot be arrived at by simple deduction from scientific knowledge, yet recognizes the role played by such knowledge. ii) The student recognizes the legitimate role of human desires and values in arriving at decisions concerning practical matters. iii) The student understands how scientific knowledge can be used as a basis for bettering our lot in everyday affairs.
ii) The student knows that biogenesis refers to a hypothesis asserting that living creatures originate only from other living creatures.	Scientific processes	i) The student identifies all independent variables in a complex experimental arrangement. ii) The student successfully controls all independent variables save one, and manipulates that one successfully.
	Structure of science	i) The student understands that biogenesis was still a doubtful hypothesis, even after Pasteur's work, and understands why it was still doubtful. ii) The student realizes that a prejudice in favour of one of two conflicting ideas can influence the interpretation of evidence. iii) The student understands how the story of biogenesis illustrates that science is a cumulative and self-correcting enterprise.
iii) The student knows that biogenesis is the hypothesis accepted by the majority of biological scientists today.		

Part C: Teaching Suggestions



INTRODUCTION

This part of the guideline contains resource material for the use of teachers. It is hoped that the suggestions found herein will assist them in their interpretation of the policy set forth in Part A.

This part of the guideline is to be considered less prescriptive than Parts A and B. As one reads through this portion of the guideline, it may appear to be telling teachers how to teach. This is not the intention. Suggestions are offered, but they are to be judged in the light of what is in the best interests of the students. If teachers wish to adopt and implement the ideas suggested, they should do so wherever feasible. However, other better or more effective ideas should be used, where appropriate and desirable.

Each of the units listed in Part A is treated in a fairly detailed way here. Each unit begins with a list of topics set forth in Part A. Opposite these topics is a suggested time frame. This time frame is for guidance only and is not necessarily to be followed. It may be interpreted as a schedule that might be applicable for certain advanced-level courses for exceptional classes where every topic could be included. Such timing is certainly not intended for all classes. However, when the curriculum is planned for any given situation, the time frame may prove useful in helping teachers to select those topics that they wish to incorporate within the available time for their students.

The expansion of each unit begins with a preamble that indicates the highlights of the unit and suggests the use of other related units. Teachers are urged to read the preamble for each unit. Following this is a number of suggestions, including activities that may be considered, factual information on some points, references to the possible development of skills and processes, occasional allusions to attitudinal emphases, questions that may be raised, cautionary advice regarding safety, directions related to plant and animal care, notes on SI units, sample problems, examples of practical applications, and other items that might be helpful. Many of the topics include a list of suggested terminology.

It is recommended that teachers examine all of this carefully and wisely, select that which is appropriate, and creatively supplement the suggestions with good material and ideas that will enhance the program for their students. Locally designed units should be similar in nature to those illustrated here.

UNIT E1: CHARACTERISTICS OF LIVING THINGS

In this core unit, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic in the unit.

Topics	Number of Periods
E1.1 Variety of organisms	1
E1.2 *Movement and locomotion	1
E1.3 *Growth	2
E1.4 *Reproduction	2
E1.5 *Metabolism	3
E1.6 Cellular basis of life	3
E1.7 *Irritability	1
E1.8 *Adaptation	1
Review and evaluation	2
16	

Preamble

This unit is designed to provide opportunities for students to observe, identify, and make generalizations about the characteristics that are common to living organisms. It is suggested that throughout this unit students examine a variety of living and non-living things. Suggestions for demonstrations and investigations are given in each topic. Topic E1.6 requires some use of microscopes. If an adequate number of microscopes is not available in a school, demonstration centres could be set up using two or three microscopes. The use of film loops and filmstrips could also help students understand the cellular basis of life.

Organisms need energy to move, respond, grow, reproduce, respire, excrete, digest, and adapt to their environment. A suggested unifying theme for this unit could be the need for energy to support these characteristics of living organisms.

This unit may be combined with the Classification of Living Things (Unit E2) and with the Interdependence of Living Things (Unit E4), if so desired.

E1.1: Variety of organisms

From their experience and first-hand observation, students should be able to identify and describe the characteristics of living organisms. Students may be given opportunities to use a variety of methods of examining living organisms. Such methods could include the observation of terraria and aquaria in the classroom, out-of-doors investigation, the observation of preserved specimens, and audio-visual presentations. The organisms studied could include examples of:

- protists, plants, and animals,
- aquatic and terrestrial organisms,
- invertebrates and vertebrates,
- those with exoskeletons and those with endoskeletons.

Refer to Appendix C for some useful suggestions on plant and animal care.

Students should be able to hypothesize and support their arguments that living things have certain characteristic properties. Living things demonstrate movement and growth, take in materials, reproduce, give off wastes, and respond to the environment. Further discussions may be stimulated by examining samples of non-living matter to identify characteristics that are common to living and non-living things.

At this stage in the unit, teachers should permit students' ideas to develop naturally. Their contributions may or may not be complete and may even be erroneous. The remainder of this topic may be used to obtain fuller answers from the students; these will lead to the development of concepts. Questions such as the following may be posed:

- Is a dried bean living or non-living?
- Is dried yeast living or non-living?
- What are the characteristics that seem to be common to the organisms observed?
- Do non-living things exhibit some of the characteristics of living organisms?

E1.2: Movement and locomotion

By observing a variety of readily available organisms, students can investigate some of the methods of locomotion. The organisms studied could include earthworms, insects, fish, frogs, and reptiles.

The movement of microscopic organisms, such as the paramecium and euglena, can be observed if microscopes of 400X magnification are available. However, films and film loops are very useful at this stage to illustrate the movement and locomotion of microscopic organisms. Suitable questions for discussion in this topic may include:

- What is the difference between movement and locomotion?
- Do all organisms exhibit movement? Locomotion?
- How are methods of locomotion designed for movement in specific environments such as the water, land, and air?
- How do plants exhibit movement?
- Is movement essential to life?

Suggested terminology: *movement, locomotion.*

E1.3: Growth

Simple investigations may be used to demonstrate growth. Students can be encouraged to hypothesize, observe, record data, and draw inferences. Investigations could emphasize experimental techniques including the use of variables and controls. Students might investigate the growth in height of a bean seedling over several days. As well, the observation of the growth of the roots of a radish, marked at intervals with ink, will help students discover the uneven growth pattern of roots. Questions for discussion might include:

- Where does the growth in the height of a plant occur?
- Where does the major growth (height) occur in mammals or humans?
- What is happening to an organism when growth occurs?

The study of the tip of an onion root or the examination of prepared slides and audio-visual materials could be used to illustrate how cell division and cell elongation contribute to growth. Since this unit is an introductory one, teachers may wish to postpone a detailed study of the root tip until Topic S1.5 on mitosis is covered.

Suggested terminology: *growth.*



E1.4: Reproduction

Students should be provided with opportunities to observe and study a variety of reproductive mechanisms. These may include examples of fission, budding, spore formation, vegetative reproduction, conjugation, pollination, and fertilization. Audio-visual material such as films may be helpful in illustrating conjugation in unicellular animals such as paramecia and unicellular algae such as chlamydomonas.

Other student activities might include the planting of a variety of seeds and the vegetative propagation of plants using slips from plants such as the geranium and coleus. Questions for discussion might include:

- Do all seeds grow at the same rate?
- Do large seeds produce large plants?
- What distinguishes sexual from asexual reproduction?
- Why is reproduction an important characteristic of all living organisms?

Teachers are referred to Continuity (Unit S10) for further information on reproduction.

Suggested terminology: *reproduction, sexual, asexual.*

E1.5: Metabolism

This topic introduces students to the metabolic processes of respiration, ingestion, digestion, and excretion.

a) Respiration:

The respiratory mechanisms of a variety of organisms could be compared. For example, the gills of fish or amphibian tadpoles could be compared to the gills of crayfish or to the lungs of terrestrial vertebrates. The specialization of structures for respiration on land and in water should be emphasized. Students should understand the need for the exchange of gases, that is, the need to get rid of carbon dioxide and to take in oxygen. Emphasis should be placed on the role of carbon dioxide in the regulation of respiration and breathing. An increase in the level of carbon dioxide in the tissue, and thus in the blood, results in an increased respiratory rate which lowers the level of carbon dioxide to normal. Students can hypothesize on and examine the effect of strenuous exercise on the respiratory rate (breathing).

b) Ingestion and digestion:

From their experience and first-hand observation of protists, plants, and animals, students can describe how organisms are designed to search for and obtain food. (Do all organisms search for food?) Students may distinguish between autotrophs (green plants) and heterotrophs (non-green organisms) and identify examples of each.

Films may be used to show the variety of digestive organs, such as the food vacuole of the amoeba and the gizzard and intestine of the earthworm. Students should distinguish between ingestion and digestion. They should understand that food is needed for energy and that energy is the ability to do work, that is, to move, grow, and reproduce.

The release of heat energy is an indicator of life in organisms and may be observed by placing a culture of yeast in a sugar solution in a thermos bottle in which a thermometer has been placed. A second thermos containing water instead of a culture of yeast may be used as a control.

c) Excretion:

Simple demonstrations may be performed to show that substances are excreted by living organisms:

- Students can exhale on a mirror or chalkboard and observe the release of water.
- Students can bubble air through a straw into a beaker of limewater. The addition of carbon dioxide will cause a milky, white precipitate of calcium carbonate to form, which on a further addition of carbon dioxide will clear.
- When a full test tube of yeast dissolved in sugar water is inverted in a beaker of sugar water, students will be able to observe bubbles of gas.

Students can answer such questions as the following by means of different techniques:

- Do plants release wastes such as carbon dioxide and water? (This question may be answered by observation and testing.)
- What happens when humans perspire? (This question may be answered through a discussion based on experience.)
- What is the function of the human kidney? (This question may be answered through the use of reference material.)
- Why is it necessary for plants and animals to excrete wastes? (This question may be answered on the basis of previous knowledge and reasoning.)

Detailed discussion of specific wastes, especially nitrogenous wastes and salts, should be avoided unless the students' backgrounds warrant such treatment of this topic.

Suggested terminology: *respiration, breathing, ingestion, digestion, waste, excretion, exhalation, perspiration.*

E1.6: Cellular basis of life

Ideally, the study of the cellular basis of life should involve the use of the microscope.

All living organisms are cellular in nature. What structures do the cells of plants, animals, and protists have in common? Students can answer this question by studying a variety of living cells such as protozoa, algae, or yeast cells. Pond water offers a variety of unicellular and multicellular organisms. Wet mounts of plant tissue such as the epidermis of elodea or the epidermal skin of an onion may be used. Cheek epithelium stained with methylene blue is also useful for microscopic work.

Have students suggest reasons for the similarities and differences among several cells that can be easily observed. Discuss only those organelles that are visible with the light microscope.

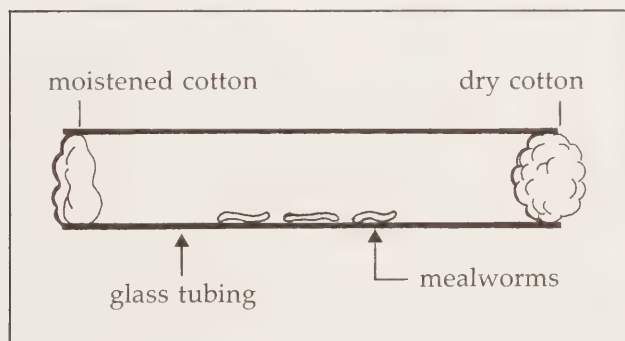
Suggested terminology: *cytoplasm, nucleus, cell membrane, cell wall, vacuole, chloroplast, cover slip, microscope slide, eyepiece or ocular lens, coarse adjustment, fine adjustment.*

E1.7: Irritability

All organisms react to their environment. This life characteristic is demonstrated in a variety of ways:

- the response of mimosa to touch
- the response of humans to cold (shivering)
- the reaction of a planarian to a light source
- the movement of a plant towards light
- the reaction of mealworms to humidity
- the response of humans to touching a hot object
- knee jerk

For example, in which direction would the mealworms move in the accompanying illustrated tube?



Note: Precautions should be taken in the use of vertebrate animals for experimentation on irritability. Refer to Appendix C on plant and animal care.

The following questions may be used to complete this topic:

- In general, how is irritability related to behaviour? Refer to Adaptation and Behaviour (Unit E7) for information.
- What are the advantages for plants and animals of being sensitive to their environment?

Suggested terminology: *the opening and closing of flowers, survival, hibernation, migration, irritability.*

E1.8: Adaptation

Once students have gained an awareness of the characteristics of living things, they can list and discuss the factors that limit or determine the distribution of organisms. Such factors could include water, light, temperature, food, predation, competition, and disease.

The concept of adaptation may be developed to include not only the immediate changes of the organism resulting from irritability, but also the long-term processes of mutation and selection.

Suggested terminology: *hibernation, migration, dormant, adaptation.*

Ontario Ministry of Natural Resources



UNIT E2: CLASSIFICATION OF LIVING THINGS

In this core unit, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

Of the topics marked by a dagger (†), at least one is obligatory.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic in the unit.

Topics	Number of Periods
E2.1 Need for classification	0.5
E2.2 Classification systems	3.5
E2.3 *Informal biological classification	1.5
E2.4 *Formal biological classification	1.5
E2.5 *Classification of plant specimens	1.5
E2.6 †Fungi	3.5
E2.7 †Mosses	
E2.8 †Ferns	
E2.9 †Seed producers	
E2.10 *Invertebrates	2.0
E2.11 *Vertebrates	
Review and evaluation	2.0
	16.0

Preamble

Since classification is a central process of organized thinking, this unit presents a unique opportunity for students to develop their knowledge and skills related to scientific classification and to gain an understanding of classification systems in general.

The realization of the need for classifying is developed by having students discover, from concrete experiences, that organized schemes are necessary for the effective understanding of phenomena and the communication of information. By actually constructing a simple classification system, students should come to understand not only some of the critical properties of classification (for example, the arbitrariness of chosen groups, increasing group specificity, and the relationships of subsets in a hierarchical system), but also that classification systems may be presented in different formats.

After the attributes of some physical system are considered, students should examine a formal biological classification system and then proceed to study briefly some representatives of this system. In general, this study is restricted to that of mature organisms. Thus, Life Cycles (Unit E11) could include further subdivisions within the categories outlined in this unit.

Upon completing this work, students will have had an opportunity to realize something of the complexities of living things. With that knowledge, they should have some appreciation of the effort and heritage behind the development of scientific classification and of its present level of complexity. The study of the arbitrary nature of classification demands of the student a degree of succinct communication and organization of thought that is essential to the development of scientific literacy.

E2.1: Need for classification

Whenever objects are grouped together for a specific reason, these objects are said to be classified. In order to show students the need for classification, they might be presented with a collection of twenty pieces of cardboard that differ only in colour, shape, and size. If they have had some experience in classification systems, this topic may be omitted or replaced by a more complex activity. The twenty pieces may be prepared for a practical activity or presented for general discussion as follows:

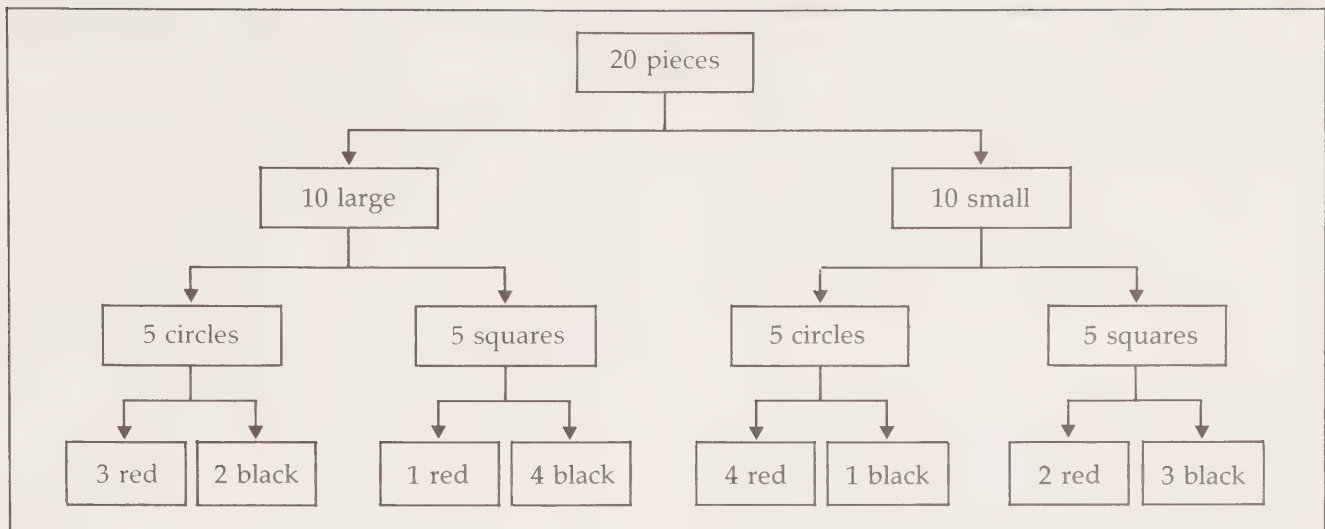
- 3 large red circles
- 4 small red circles
- 2 large black circles
- 1 small black circle
- 1 large red square
- 4 large black squares
- 2 small red squares
- 3 small black squares

Students could then be asked to describe accurately the contents of this set, which is presented to them in a jumbled order. The pieces of cardboard could be sorted and listed as shown above. Some students will note that there are ten circles and ten squares; others will find that ten are red and ten black; and still others that ten are large and ten small. To simplify the task of describing the entire set, students should classify the items according to various attributes, such as size, colour, or shape. In this way, a variety of classifications will result, a number of which should be discussed.

Suggested terminology: *classification, attribute.*

E2.2: Classification systems

On the chalkboard, a comparison may be made of some systems of classification that arise from the students' suggestions. Sometimes a tree diagram will help demonstrate a classification system, as shown in the following illustration:



Each piece has all three attributes: colour, shape, and size. Thus, a cross-classification table may be devised, since each cardboard piece belongs in various subsets.

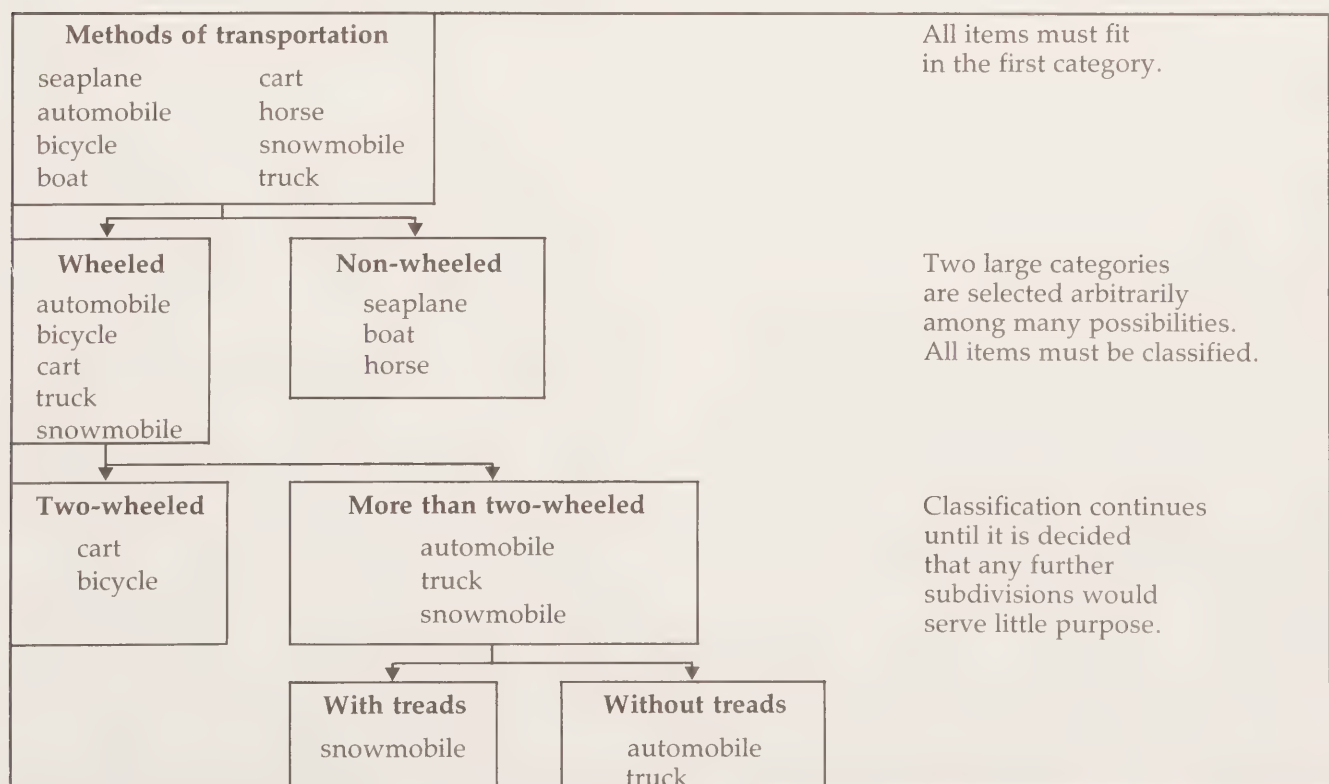
Shape	Size	Red	Black
circles	large	3	2
	small	4	1
squares	large	1	4
	small	2	3

Students may be asked what would happen if pieces of another colour were added to the set. They should naturally deduce that an additional extension would be required in the classification scheme.

To further develop the concept of classification systems used in science, the following list may be given to the students.

Methods of transportation	
seaplane	cart
automobile	horse
bicycle	snowmobile
boat	truck

How would they classify these? What system could be used? Several classification schemes may be discussed. Here is a possibility:



All items must fit in the first category.

Two large categories are selected arbitrarily among many possibilities. All items must be classified.

Classification continues until it is decided that any further subdivisions would serve little purpose.

Here it should be pointed out that a cross-classification table would not be suitable, since the objects classified do not have multiple-membership across all of the classes. Each item does not exhibit all attributes used in the classification system as was the case in the set of twenty cardboard pieces. For instance, there is no need to classify any item in this second example under “non-wheeled with treads”.

An activity may be given based on the following set of nonsense words:

ankow	elting	lofly	qwamp
arlerly	frand	largly	trokke
bilq	igortly	mober	unding
croming	himing	nykly	vaberly
druper	lowikor	opp	wobing

Since the words have no meanings, they may be classified according to such characteristics as the number of letters or syllables they contain, whether they begin with a vowel or consonant, whether they do or don't contain blends, their prefixes or suffixes, and so on. Students should be encouraged to decide on categories of their own. Some students may be able to give practical reasons for classifications of words: for example, by numbers of letters to find words for solving crossword puzzles or by numbers of syllables to choose words to use in writing poetry. This activity emphasizes the “structure” of word formation.

Another set of words adds a new dimension – that of meaning – and, therefore, adds a new challenge. Both the “structure” of the words and the “function” of what they mean can enter into the possible classification schemes. Students should try to classify the following words with a specific purpose in mind.

ant	dog	motor	scarf
berry	grape	prune	shoe
beaver	hat	pulley	sure
cat	liver	pure	true
cherry	log	rat	very

Here, rhyming words (berry, cherry, very) or fruits (berry, cherry, grape, prune) may be classified for different purposes.

Students may now realize that in classifying a set of items they should consider such questions as the following:

- What is the purpose of the classification system?
- Does the system need to be uniform or should the various branches differ in the number of groups shown?
- Are the descriptions of the various groups clearly defined so that anyone using the system would readily group the items in the same way?

Suggested terminology: *classification system, tree diagram, cross-classification table.*

E2.3: Informal biological classification

This topic could be combined with Characteristics of Living Things (Unit E1) to focus student attention on the difficulties inherent in classifying a wide variety of diverse specimens.

Students may be given a number of organic and inorganic materials or specimens to classify. Actual specimens may be used where possible, but pictures and diagrams may be substituted where necessary. There may be several duplicates, if desired. Examples may include rocks, mushrooms, insects, worms, metals, fabrics, crayfish, cones, flowers, weeds, frogs and toads, mosses, ferns, moulds, house plants, spiders, and salamanders.

A classification activity could proceed as follows:

- division of specimens into two groups: living and non-living or organic and inorganic;
- further division into plant and animal;
- further subdivision based on characteristics such as locomotion, presence of leaves, number of legs;
- completion of the classification system with a sufficient number of subgroups that are meaningful to the students.

Suggested terminology: *organic, inorganic, living, non-living, plant, animal.*

E2.4: Formal biological classification

Students should understand that biologists generally classify organisms according to structure. The categories in this system, proceeding from general to specific, should be discussed and illustrated with examples of a kingdom, phylum, class, order, family, genus, and species. Some examples may be derived from the previous topic. The necessity of universal terminology (Latin) should be noted. Some mention might be made of the historical development of biological classification or taxonomy with particular reference to the work of Linnaeus.

The following topics are based on a four-kingdom classification – plants, animals, protists, monerans – which is in wide use today. However, since biology is an evolving science, changes are naturally evident in classification. A five-kingdom classification has been proposed and is gaining acceptance. In this particular taxonomy, fungi are considered to be a separate kingdom. If the teacher wishes to use a five-kingdom classification, then Topic E2.5 should become E2.6 and the accompanying diagram adjusted accordingly.

Suggested terminology: *kingdom, phylum and phyla, class, order, family, genus and genera, species, taxonomy.*

Note: The function of the following topics is to strengthen the students' understanding of the basic principles by which organisms are classified. Certain representative plants and animals can illustrate the principles involved.

It is not necessary for students to work through all the content that follows. Rather, selected examples could be chosen to exemplify the concepts suggested earlier in this unit.

It is important that students derive the characteristics of each group of plants and animals, wherever possible, by examination of external features and habitat. Highly detailed examination of representative organisms should be avoided.

Individual plants and animals studied should be shown to fit into the formal biological classification system mentioned in Topic 2.4.

E2.5: Classification of plant specimens

With hand lenses and microscopes, students should carefully examine specimens of fungi, mosses, ferns, and seed-producing plants. These should include the following:

- fungi – black mould as found on bread; blue mould as found on citrus fruit; mushrooms; bracket fungi as found on dead trees; puffballs; and yeast;
- mosses – true mosses (complete plant);
- ferns (complete plant);
- seed producers – angiosperms and gymnosperms showing branches and cones.

Students may develop the following classification scheme after the foregoing examination. Relevant vocabulary could be introduced as needed.

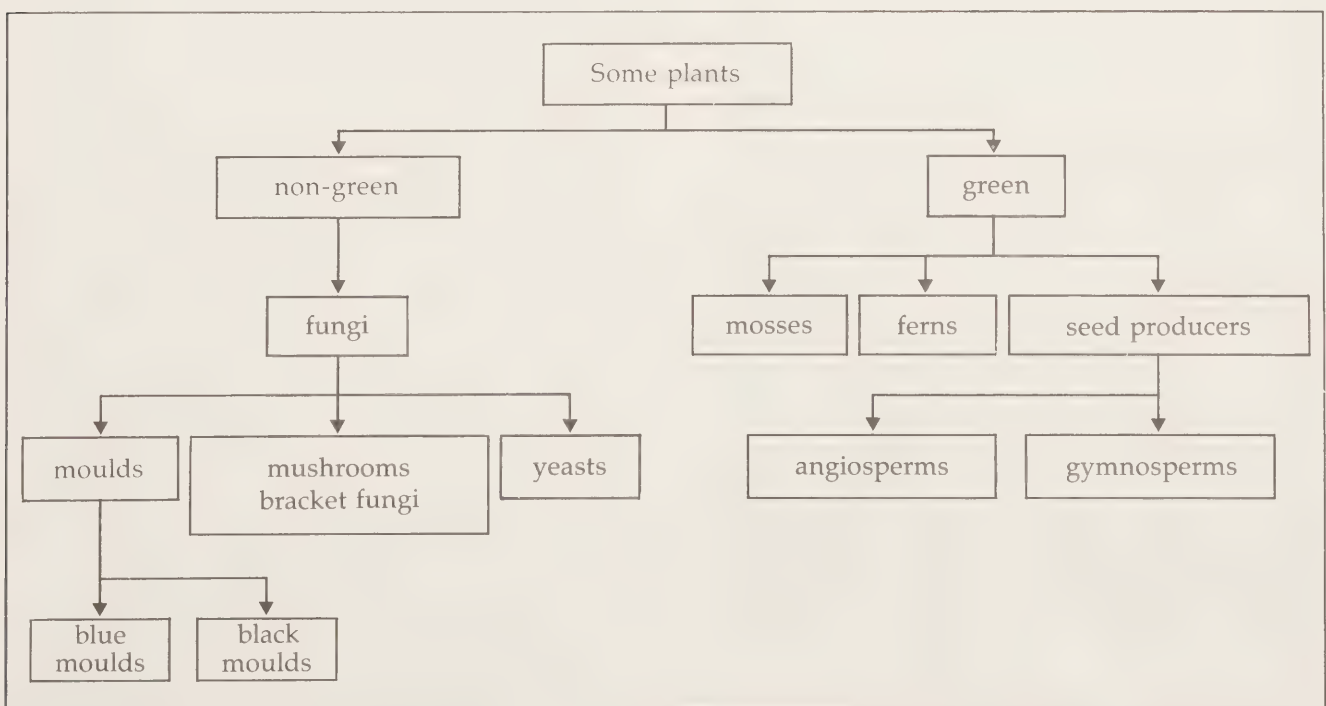
Suggested terminology: *mould, bracket fungi, yeast.*

E2.6: Fungi

Fungi may be studied as follows:

- General characteristics that should be apparent are the lack of roots, stems, leaves, and flowers, and the fact that fungi do not manufacture their own foods. "How then do they live?" is a natural question that should arise.
- A representative fungus may be studied to note its external features and habitat.

Suggested terminology: *fungus* and *fungi*.



E2.7: Mosses

Mosses may be studied as follows:

- General characteristics that may be noted are that mosses are small green plants found in moist areas and that they have structures that resemble roots, stems, and leaves, but are not such, since they lack channels for carrying fluids.
- Moss plants may be observed in order to note their external features and habitat.

Suggested terminology: *moss*.

E2.8: Ferns

Ferns may be studied as follows:

- General characteristics indicate that ferns are commonly found on moist forest floors and that they do have roots, stems, and leaves.
- A number of ferns should be examined to note such external characteristics as underground stems or rhizomes, roots, and leaves.

Suggested terminology: *fern*, *rhizome*.

E2.9: Seed producers

Seed producers may be studied as follows:

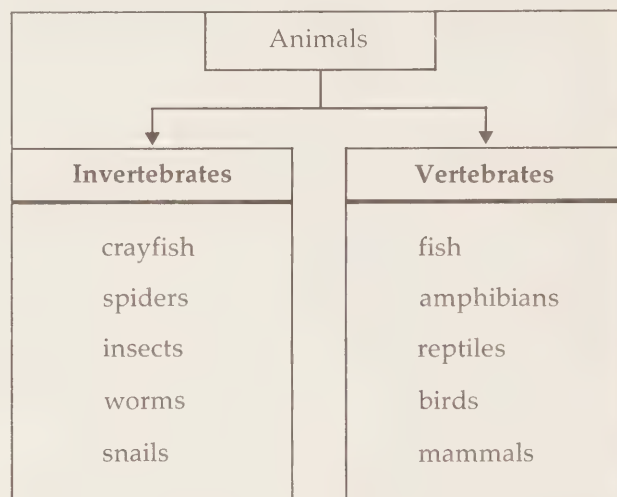
- General characteristics support the fact that these include most of the world's plant population, and that there are two types: gymnosperms that produce cones such as the pine; and angiosperms that produce flowers that are not in the form of cones.
- A commonly occurring gymnosperm should be examined to note the shape and arrangement of needles and the characteristics of the cones.
- Common angiosperms should be examined to note the colours of the flowers, the shapes of the leaves, the types of fruit, and so on.

Suggested terminology: *seed producer*, *gymnosperm*, *angiosperm*.



E2.10: Invertebrates

The following kinds of specimens may be obtained (or good pictures or diagrams may be substituted) for purposes of classification: grasshoppers, butterflies, moths, worms, ants, snails, beetles, crayfish, spiders, frogs, fish, snakes, birds, and small animals. *Note: Teachers who wish to have vertebrates in the classroom should read Appendix C. Students should be encouraged to classify all these animals into two groups and to define the name of each group. If time permits, subgrouping could be carried out to show further extensions of the classification system as follows:*



One or two examples of invertebrates could be examined briefly to note body structures, sense organs, and locomotion.

Suggested terminology: *invertebrate*, *vertebrate*.

E2.11: Vertebrates

Some examples of vertebrates should be briefly examined. They should have an enclosed spinal-cord backbone, a well-developed brain, and an internal skeleton. Well-known classes of vertebrates include mammals, reptiles, amphibians, fish, and birds. The chief characteristics of each could be noted. One specimen from any of these groups may be studied in more detail with respect to body structure, sense organs, and locomotion. (See Appendix C on plant and animal care.)

Before completing this unit, students should be made aware that although the scientific classification system mentioned in Topic 2.4 is very precise, many reference books are only partly based on this taxonomy. Many books classify animals by locomotion or colour or some other characteristic for ease of use and identification by non-scientists.

Suggested terminology: *mammal*, *reptile*, *amphibian*, *fish*, *bird*.

UNIT E3: FORCE AND ENERGY

In this core unit, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic in the unit.

Topics	Number of Periods
E3.1 Examples of forces	1
E3.2 *Measurement of forces	1
E3.3 *Force of gravity	1
E3.4 *Force of gravity and its relationship to mass	1
E3.5 *Work	1
E3.6 *Measurement of work	1
E3.7 *Energy	0.5
E3.8 Potential energy	2.5
E3.9 Kinetic energy	1
E3.10 *Forms of energy	1
E3.11 *Energy conversion	1
E3.12 Wise use of energy	1
Review and evaluation	2
	15

Preamble

Mechanics involves, among other concepts, the study of force, work, and energy. Although some of these ideas are abstract, students usually have an intuitive feel for them. They exert forces from the time they are born, they do work (in the physical sense), and they have boundless energy (most of the time).

Experimental activities will make this unit interesting and will enable students to understand the scientific concepts. Students should be given opportunities to exert forces, to do work, and to permit the transfer of energy. In a sense, their muscles and limbs could be part of the "laboratory apparatus".

An important aspect of this unit is the adoption of certain SI units, which are comparatively new to most teachers. The newton and the joule – units of force and work, respectively – are not difficult for students to understand at the Grade 7 and 8 levels. It will be essential for classes to be equipped with newton spring scales for measuring forces.

Adults who are familiar with the former metric system have become accustomed to the gram and kilogram as units for both mass and force. This is no longer to be the practice. Mass should be called "mass", not "weight", and should be measured in grams and kilograms. Force, including the force of gravity, should be called "force" (or "force of gravity"), not "weight", and should be measured in newtons and kilonewtons. If students realize from

the outset that mass units and force units are quite different, they will have no difficulty distinguishing between them in later courses.

By the end of this unit, it is desirable, among other objectives, for students to have an understanding of the concepts of force, work, and energy; to be able to differentiate between mass and force of gravity; to know and use the SI units of measure for force and work; to understand the difference between potential and kinetic energy; to be able to identify a variety of forms of energy; to appreciate that although energy is convertible and universally conserved, it can be wasted thoughtlessly; and to be willing to make wise use of energy resources.

E3.1: Examples of forces

Through a series of simple demonstrations, students could arrive at the meaning of the term "force". For example, students could:

- pull on a desk (it may or may not move);
- push against a wall;
- pull a brick up a ramp;
- squeeze some plasticine;
- stretch some chewing gum or an elastic band;
- lift an apple;
- bite the apple;
- blow against a candle flame.

The meaning of force should be expressed in non-technical terms that can be as simple as "a push" or "a pull".

Various kinds of forces and their names should be discussed. Where feasible, students can experience some of them, such as:

- elastic force – the pull of a stretched elastic band or spring; the push of a squeezed sponge;
- magnetic force – the pull of a magnet on a nail or the pull of the nail on a magnet; the repulsion of two like poles;
- tension force – a string attached to a brick is limp until there is a tension (pulling force) in the string (when it is used to pull on the brick);
- compression force – a vise grips a piece of wood and compresses it (pushing forces); the roof exerts a compression force downwards on the supporting walls; when students stand, they exert a compression force on the flesh on the bottoms of their feet;
- shearing force – cutting as in shearing sheep; the action of scissors or a paper punch;
- electric force – after combing a student's hair, a comb is used to pick up some confetti or to pull a very fine stream of water from a tap to one side. Some electric forces repel;
- friction force – when an object slides over a surface, friction tends to oppose the motion. Friction can be useful, by providing traction, for example;
- gravitational force or force of gravity – the downward force or attraction exerted by the earth on an object.

Suggested terminology: *force, attraction, repulsion, magnetic, elastic, tension, compression, shearing, electric, gravitational, friction.*

E3.2: Measurement of forces

If forces are to be measured, a device has to be set up so that a known force is balanced against the unknown one. Students could make their own force-measuring device. One end of a spring or of an elastic band is attached to a board. The spring or band is stretched over a centimetre scale whenever it exerts a force on something. The students can devise their own arbitrary units of force. Such questions as "If the force is doubled, is the stretch doubled?" and others could be investigated as time permits. However, it is suggested that spring scales calibrated in newtons be used by students as soon as possible. A newton may be described as being roughly equal to the force required to support two golf balls or a single D-cell flashlight battery.

Students should have ample opportunity to measure a number of forces of different kinds and to get the feel of a 1 N, 5 N, 10 N, 20 N, 50 N force, and so on. After a little practice, guessing an unknown force before measuring could be a useful and enjoyable experience.



If students have made their own "force meters", they may wish to calibrate them in newtons. They should realize that the newton is the SI unit of force, and that the symbol N for newton is capitalized because it is named after Sir Isaac Newton.

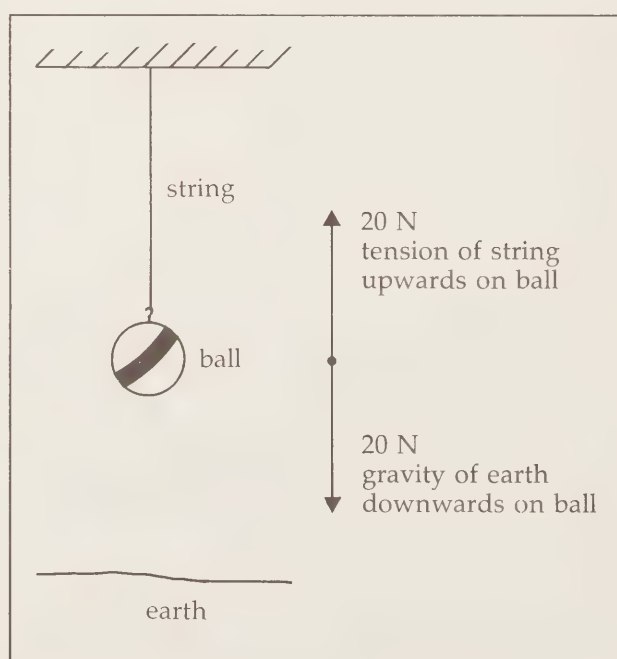
The millinewton (mN) and the kilonewton (kN) may be mentioned in passing as examples of sub-multiples and multiples of the newton. Measurements in these units are not likely to occur in the classroom.

At this stage, there is no need to refer to the acceleration of a mass in connection with a formal definition of the newton. This should be reserved for more advanced courses in science.

Suggested terminology: *spring scale, newton*.

E3.3: Force of gravity

A ball, suspended from the ceiling, may be observed by the students. They should recognize the forces acting on the ball and what these forces are exerted by. They should be able to draw a "force diagram" to represent the forces. The forces are shown by means of arrows and should be labelled to indicate what is exerting the force. Forces of equal magnitude should be shown by arrows of equal length. (A formal vector treatment of forces is not necessary at this stage.) A newton spring scale inserted in the string that supports the ball will enable students to measure the supporting force. If the string is pulling upwards on the ball, what is pulling it downwards? (Answer: *the earth*.) How does the upward tension in the string compare with the downward pull by the earth? These, and similar questions, should lead students to define the "force of gravity" as the downward attraction of the earth on an object. To find the magnitude of this downward pull, we can measure the equal (but opposite) supporting force in newtons.



In the past, the downward force of gravity has often been called the “weight” of an object and has frequently not been measured in newtons. It is recommended that the term “weight” not be used to refer to the force of gravity acting on an object. This force is simply called the “force of gravity”.

Students should have the opportunity to determine the force of gravity acting on a number of objects. As they do this, they need to realize that they are actually measuring an upward-supporting force that exactly balances the downward force of gravity exerted by the earth. The effect of the buoyancy of the air should be omitted.

Suggested terminology: *force of gravity, newton spring scale.*

E3.4: Force of gravity and its relationship to mass

In this activity, students should use a lever-type balance to measure masses in order to distinguish this operation from the measuring of forces by means of a newton spring scale. Spring balances calibrated in grams or kilograms should not be used when studying this topic. The question “How is the force of gravity acting on an object related to its mass?” could be investigated. Students would measure the mass, in kilograms, of several objects. They would then measure the force of gravity acting on each of these objects. The set of corresponding masses and gravity forces could then be compared in a table or by means of a graph. In SI, the preferred unit of mass is the kilogram and the preferred unit of force is the newton; these units should be used in this activity.

In general, it is suggested that objects ranging between 0.5 kg and 5 kg be used if possible. A 50 N spring scale would be needed to measure the force of gravity. Typical results may be tabulated as follows:

	Mass	Force of gravity
Object A	0.5 kg	5 N
B	1.0 kg	10 N
C	1.5 kg	15 N
D	2.0 kg	20 N
E	3.0 kg	29 N
F	5.0 kg	49 N

Students should find examples such as the following: A brick might have a 2 kg mass requiring 20 N to lift it. The force of gravity acting downwards on the brick is then 20 N. Similarly, a 0.5 kg bag of sugar would be found to have a 5 N force of gravity acting on it.

It should be found that each kilogram of matter has a force of gravity acting on it very nearly equal to 10 N. It is closer to 9.8 N, but 10 N is a good approximation. This relationship between the force of gravity and the mass of an object, namely, that *there is a 10 N force of gravity acting on each 1 kg of mass*, should be well established with students.

Students can determine the force of gravity acting on their own masses, which can be measured by having them stand on a bathroom scale that is calibrated in kilograms. If a student has a mass of 45 kg, the force of gravity acting on him or her is 450 N downwards. He or she must exert a force of 450 N when climbing vertically upwards against the force of gravity.

The differences between the mass of an object and the force of gravity acting on it should be discussed. What happens to the mass of a 5 kg block of steel and to the force of gravity on it if it is first on the earth, then on the moon, and then on Jupiter? (The mass remains at 5 kg, but the force of gravity changes from 50 N on earth, to 8 N on the moon, to 130 N on Jupiter.)

E3.5: Work

The meaning of the word “work” should be discussed. Students should realize that in science a definition may limit the meaning of a word for scientific purposes. Is work done when a student studies for a test, pushes against a wall, holds a heavy suitcase in an interminable line-up, or winks at a friend?

“Work” can be defined as “force times distance”, that is, work is done when a force succeeds in moving something. The work must be done on a mass by an agent that exerts a force that moves the mass. The work is done when the force is used to move an object through a distance in the direction of the force. The amount of work is determined by multiplying this force by the distance moved.

This leads to the equation $W = Fd$, where W represents the work done, F the force exerted, and d the distance moved. (Strictly speaking, the distance is the displacement, that straight-line distance from the initial point to the final point of motion in the direction of the force.) Most problems should, therefore, be restricted to straight-line motion. A full vector treatment should be reserved for later courses in science.

When work done is determined, the force should be measured in newtons and the distance in metres. The product of force times distance could then be expressed in newton metres, but a newton metre is called a joule (J). Students should be able to solve problems to find the work done when the force and distance are given, using the relationship: work done in joules = force in newtons $\times$ distance in metres. Brief reference should be made to the kilojoule (kJ) and the megajoule (MJ), and the fact that the joule is named after the English physicist James Prescott Joule.

Suggested terminology: *work, joule, kilojoule.*

E3.6: Measurement of work

Activities could be set up to measure the amount of work done in various situations, such as the following:

- a student dragging a brick (wrapped in cloth or carpet) along the floor;
- a student pulling the brick up a wooden ramp;
- a student lifting the brick straight up from the floor to a desk top;
- a student climbing a rope in the gymnasium;
- a student climbing a flight of stairs;
- a toy tractor pulling a wooden block across the room;
- a tractor lifting a block from the floor to a desk top by means of a pulley;
- a student carrying his or her textbooks up to the next floor;
- a student pulling another on a toboggan in the snow or on a trolley in the hall through a given distance.

Students will have to take an average reading on the newton spring scale during an activity. When movement is through a vertical height, the gravity-mass relationship of 10 N acting on each kilogram may be used.

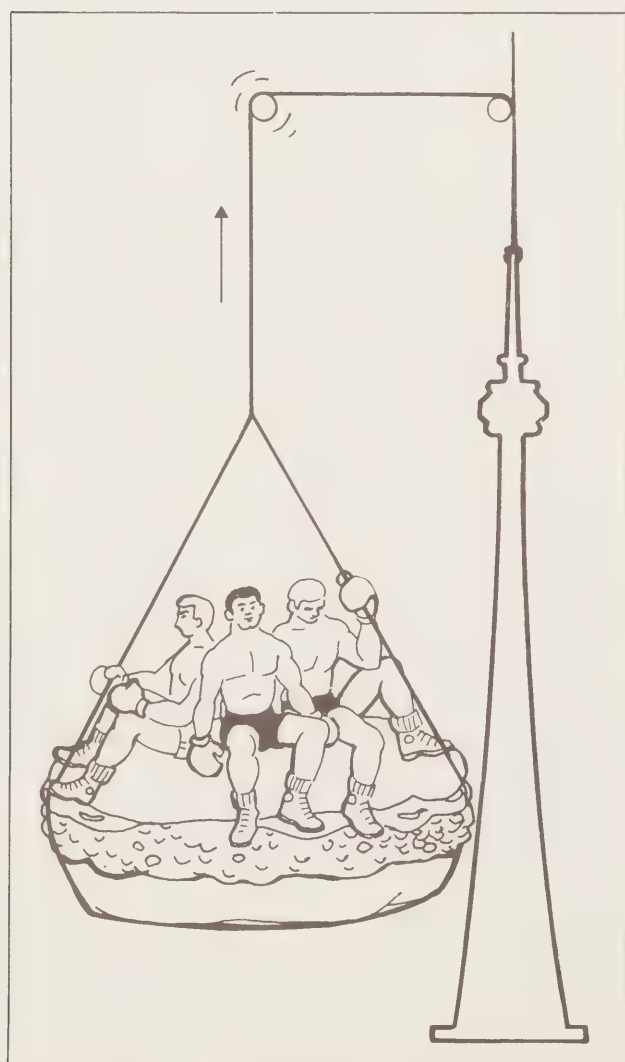


E3.7: Energy

The need for a person to possess energy if work is to be done could be discussed. Energy can be defined as the ability to do work, that is, the ability to exert a force on something and to move it. The idea that the units for measuring work and energy are the same – namely, the joule, kilojoule, megajoule – should be stressed.

Body energy should be related to food intake. The energy value of foods is expressed in kilojoules in SI and not in Calories as in the past. Some examples of food-energy values expressed in kilojoules should be given. One of these may be equated with an amount of work done by a force and exerted through a distance. For example: A hamburger with bun has an energy value of about 1500 kJ. $1500 \text{ kJ} = 1\,500\,000 \text{ J} = 3000 \text{ N} \times 500 \text{ m}$. A force of 3000 N can lift a mass of 300 kg (roughly three heavyweight boxers) vertically upwards. 500 m reaches very nearly to the top of the CN Tower in Toronto. Therefore, the food energy content in a hamburger is equivalent to the work that would be done in lifting three large men to the top of the CN Tower. Students should now be prepared to do some work to dissipate some of that hamburger energy.

Suggested terminology: *energy*.



E3.8: Potential energy

Examples of stored energy could be discussed and the term “potential energy” defined, perhaps in the following terms:

- Potential electric energy is stored in a battery.
- Potential chemical energy is stored in an Alka-Seltzer tablet.
- Potential mechanical energy is stored in a toy that is fully wound up.
- Potential thermal energy is stored in fuel oil.

Consideration should be given to “gravitational potential energy”. What does a brick have, 2 m above the floor, that it does not have when resting on the floor? (*It has stored energy.*) Why? How does the brick gain this property? How can it gain more? How can it lose it? These and other questions may be used to indicate the concept of potential energy being stored in a mass when work is done on it to raise it to some height.

Can a student be sure that if the mass were doubled or if the height were doubled, then the potential energy must be doubled also? This could be left unanswered, and the students could be allowed to investigate possible forms of evidence.

If energy is the ability to do work – that is, to exert a force on something and to move it – perhaps the potential energy of a marble or steel ball can be measured roughly in arbitrary units. Students can roll marbles or steel balls of different masses down ramps of different heights. The amount of work done by the marbles or balls is indicated by how far they move a wooden block with which they collide at the bottom of the ramp.

Here, students could decide which variable they are going to test (mass or height) and which must remain constant. They could be given the opportunity to graph the work done on the block against either variable in order to answer the question posed above.

Do any other factors affect the gravitational potential energy of an object? If this is not answered by the students, a hint might be given by asking another question. Which would hurt your foot less, the fall of a brick from a counter 90 cm high on the earth or on the moon? Footwear is not to be a variable.

Suggested terminology: *potential energy*.

E3.9: Kinetic energy

Kinetic energy can be defined as the energy of an object due to a combination of its mass and speed – no speed means no kinetic energy. Students could give examples of objects that have kinetic energy.

The ramp activity in Topic 3.8 can be recalled and questions such as the following can be asked:

- When a ball or marble rolls down the ramp, what is happening to its height? Its potential energy? Its mass? Its speed? Its kinetic energy?
- Which kind of energy is decreasing and which is increasing?

- Do you think that one form of energy is changing into the other? Completely?
- If we could determine both kinds of energy, in what SI units should they be expressed?

It can be pointed out that further studies would show that apart from energy loss due to factors such as friction and air resistance, the kinetic energy of the ball at the bottom is equal to the potential energy of the ball at the top of the ramp. However, this has not been proved or measured by the students at this stage, and it cannot necessarily be taken for granted. Students must not make assumptions without ample evidence, and this topic presents an opportunity to underline this problem.

A similar point may be made with a second example: If either the mass or the speed of the ball at the bottom of the ramp is doubled, is its kinetic energy doubled? (Answer: *for doubled mass, yes; for doubled speed, no!*) The point here is not to teach the students the relationship between kinetic energy, mass, and speed, but to ensure that they do not carry away with them any misconceptions.

Suggested terminology: *kinetic energy*.

E3.10: Forms of energy

In order to determine what different forms of energy exist, such forms of energy as the following may be discussed and illustrated:

- mechanical energy – a wind-up toy tractor crashes into a pile of blocks; a saw cuts wood; an arrow is released from a bow;
- electric energy – an electric fan is turned on;
- chemical energy – sulphuric acid is added carefully to an aqueous sugar solution (teacher demonstration);
- thermal energy – a piece of paper is moved slowly towards and through a flame (and disposed of safely);
- acoustic energy – a blaring radio program is suddenly turned on;
- light energy – a strong light beam is momentarily flashed into a person’s eyes;
- gravitational energy – a falling mass pulls a small container upwards by means of a pulley.

How do we know that these are forms of energy? In each activity or demonstration, the energy may be detected because something reacts in response to the energy transfer: the blocks are toppled, the wood turns into sawdust, the arrow flies through the air, the blades of the fan rotate, the sugar releases carbon, the paper burns, the radio program causes vibrations in the eardrums, the light beam makes the eyes squint, and the container moves upwards.

Suggested terminology: *mechanical, electric, chemical, thermal, acoustic, light, and gravitational forms of energy*.

E3.11: Energy conversion

Students should be able to give a number of examples where one kind of energy (potential or kinetic) or one form of energy (mechanical, electric, chemical, thermal, gravitational, etc.) is converted into another. Examples can be taken from situations found in the home, school, car, shopping plaza, ballfield, electric power plant, industry, while on vacation, and so on. Demonstrations of a few conversions could be given, such as:

- the striking of a match;
- the swinging of a pendulum;
- the falling of water from a tap to turn a small generator that lights up a bulb.

The law of conservation of energy could be discussed, and some reference made to an equation such as $\text{input energy} = \text{output energy} = \text{useful energy} + \text{wasted energy}$. For example: all the energy that goes into a school eventually comes out, some of it being useful and the rest wasted.

Suggested terminology: *conversion, conservation.*



E3.12: Wise use of energy

This topic may be further expanded into a full unit of study to be designed by the local school board. Here, it may be limited to a brief discussion of attitudes towards the use and misuse of the limited non-renewable sources of energy that are now available. Students should understand the "energy crisis" and the role of each student and individual in preventing it. A discussion of the utilization of such forms of energy as wind, solar, and nuclear energy could be included in considering our energy problems.

Suggested terminology: *fossil fuel, non-renewable energy.*



UNIT E4: INTERDEPENDENCE OF LIVING THINGS

In this core unit, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic in the unit.

Topics	Number of Periods
E4.1 *Natural communities	10
E4.2 *Concept of an ecosystem	
E4.3 *Types of communities	
E4.4 *Producers, consumers, and food chains	
E4.5 Photosynthesis and respiration	
E4.6 Biological change	2
E4.7 *Disturbance of balance	
E4.8 *Human influence	
Review and evaluation	2
	16

Preamble

The life of every organism is affected by its environment and by the lives of other organisms as well. This unit is designed to give students opportunities to observe and investigate simple ecological relationships. In addition, it is expected that students will extend their understanding of these relationships to the human community when it is examined.

Activities such as the examination of natural communities and the observation of simple ecosystems can provide students with opportunities for understanding and applying certain principles studied in class. It is suggested that students be given some opportunity to examine an indoor community, such as an aquarium or terrarium, and also an outdoor community, such as a forest, field, pond, or stream.

This unit will give students a basic introduction to the science of ecology. Further development of the concepts outlined in this unit will be continued in Populations and Communities (Unit S7) and Terrestrial and Aquatic Environments (Unit S20).

E4.1: Natural Communities

The concept of a community can be developed by using communities that are familiar to the student, such as a town, a school, or a farm. A community may be defined as "a group of populations that interact with one another in a specific location". The students should distinguish between a population and a community.

By contrasting the human community with a natural community such as a forest, students should be able to identify specific populations. Smaller communities in the form of terraria or aquaria may be used in the classroom to illustrate the plant and animal components of a natural community. By comparing the human community with a natural community, such as a forest or a pond, students should be able to predict and discuss, in general terms, the relationships that exist within a community. Such relationships could include competition, dependence, and assistance.

Suggested terminology: *population, community, terrarium, aquarium.*

E4.2: Concept of an ecosystem

An ecosystem or ecological system encompasses the interrelationships of its living organisms and its non-living environmental components. Students could investigate the living and non-living aspects of an ecosystem by preparing some samples of closed ecosystems, such as terraria and aquaria, for the classroom.

- What are the living components of an aquarium?
Of a terrarium?
- What are the non-living components?

Suggested terminology: *ecosystem, ecology, inter-relationship.*

E4.3: Types of communities

Students can investigate the living and non-living factors affecting terrestrial and aquatic communities, such as a forest, a field, some soil, a pond, or a stream. If possible, this topic could begin with a field trip to examine a specific plant-animal community and habitat. Students should be involved in choosing the community to be studied. They should be able to identify some observed populations and to record useful information. Simple relationships among organisms should also be observed and recorded.

Students should bring to class samples of soil from different regions, such as fields, forests, or swamps. These samples can be examined under a microscope or with a hand lens. Students should be able to determine what organisms and what plant materials are present.

They can then develop the idea of the interdependence of these plants and animals.

Suggested terminology: *habitat, interdependence, terrestrial*, plus any vocabulary that may be generated by a field trip.

E4.4: Producers, consumers, and food chains

Students can use the variety of plant and animal life observed during field studies to develop and write simple food chains. A typical food chain could be: grass → rabbit → fox. Students can consider the human community. How are the students part of food chains? They can then write several simple food chains that include humans.

The following are examples of questions that could further develop an understanding of the concept of food chains:

- Of what importance is grass in a food chain?
- What role does an animal play in a food chain?
- Which organism is the producer?
- Are humans producers or consumers? Explain.
- What role is played by decomposers?
- Which organisms are decomposers?

Suggested terminology: *food chain, producer, consumer, decomposer*.

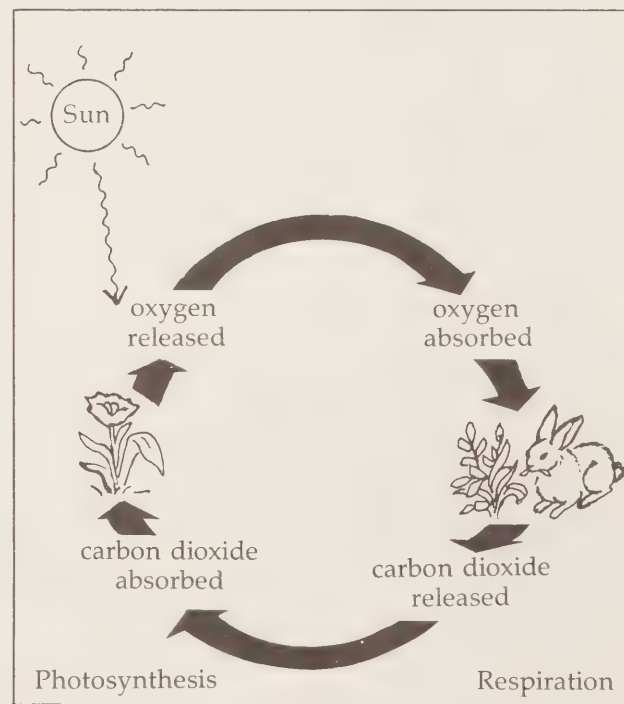
E4.5: Photosynthesis and respiration

A food chain can be discussed in terms of energy flow. Students should recognize green plants as producers. The role of green plants in the conversion of light energy into food energy that can be used by both plants and animals can be discussed.

The term “chemical energy” may be introduced, but may not be familiar unless it has been mentioned in some previous unit. The teacher may wish to refer to Photosynthesis (Topic S4.3) in Green Plants (Unit S4) for suggestions regarding investigations to demonstrate the reactants and products involved in the chemical process of photosynthesis. Undue overlap between this topic and its treatment in Unit S4 should be avoided.

Students could suggest why plants and animals need each other. This can lead to a discussion of the cycling of carbon dioxide and oxygen, illustrated here. It is suggested that the details of the carbon dioxide-oxygen cycle be left to Populations and Communities (Unit S7).

Suggested terminology: *photosynthesis, respiration, oxygen, carbon dioxide*.



E4.6: Biological change

Biological communities change over a period of many years. Students can suggest examples of short-term changes that are familiar to them. Such changes could include the gradual changes in a deserted farm, an abandoned section of highway, or even an unkept lawn.

What is meant by “biological change”? A detailed discussion of primary and secondary succession should be avoided. Refer to Populations and Communities (Unit S7) for more details on this topic.

E4.7: Disturbance of balance

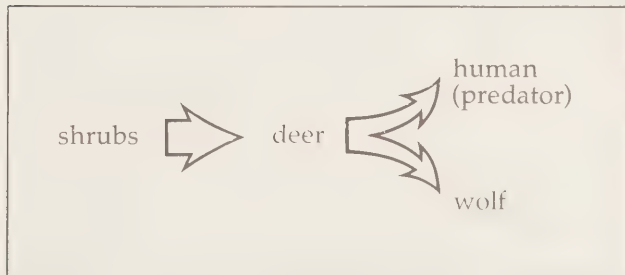
Plant and animal communities are often radically altered by disturbances in their environments. These disturbances include floods, fires, earthquakes, disease, and changes in climate. A specific example such as fire can be used to illustrate how plant and animal communities are affected. Is fire necessarily harmful? Small ground fires may be used by forest managers to initiate the release of seeds from the cones of jack pine and black spruce. Ground fire can also remove the dense layer of slash in forests. What are the effects of longer-lasting, uncontrolled fires on the balance of nature?

Students could make a list of at least five beneficial changes that humans have made in the biosphere. For each item on the list, students can write down a possible harmful result of the change. For example, our use of pesticides results in the death of many birds; the use of penicillin produces bacteria that are resistant to penicillin. These results can be discussed and clarified. Students should be encouraged to think of ways of becoming involved in improving their environment.

Suggested terminology: *biosphere, food chain, food web, predator.*

E4.8: Human influence

Students could debate and resolve, to some extent, the question of the impact of humans on plant and animal communities in their immediate environment. What are the problems or issues that have arisen as a result of human influence on the biosphere? How do humans contribute to the balance in such a food chain as:



The advantages and disadvantages of hunting laws could be discussed.



UNIT E5: MEASUREMENT

In this core unit, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic in the unit.

Topics	Number of Periods
E5.1 The need for quantitative description	0.5
E5.2 Physical quantities and their units	0.5
E5.3 *Linear units	2
E5.4 Averaging	1
E5.5 Rounding	0.5
E5.6 *Area units	1.5
E5.7 *Volume units	3
E5.8 *Mass units	2
E5.9 *Time units	2
E5.10 *Temperature units	1.5
E5.11 Rate of change	1.5
Review and evaluation	2

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Preamble

The treatment of this unit on measurement will depend a great deal on the previous experience of the students with the metric system. If they are familiar with the common units, prefixes, and symbols, time should not be wasted on unnecessary repetition. Much of the unit could be an overview, with opportunities given for a variety of first-hand experiences in measuring.

At this level, there is no need to deal with the structure of SI, but it should be pointed out that there is a single primary SI unit for each physical quantity: metre for length, square metre for area, cubic metre for volume, kilogram for mass, and so on. All other units are multiples or submultiples of these primary SI units. This concept will prepare students for later work in science, when they will focus their attention on the single SI unit that dominates each kind of physical quantity.

Some problem-solving is recommended, but the mathematics involved should not be a barrier to student understanding of measurement. Mathematical conversions between metric and imperial units are to be avoided. Where textbooks have not been updated to conform with SI, it is suggested that teachers have students annotate the texts with metric versions of problems wherever feasible.

Measurement concepts should constantly be related to practical applications in real life. It is paramount to a student's understanding that he or she visualize, for example, an actual hectare of land

in some familiar location and not just think of it as 10 000 m². This mental picture will help make meaningful for students such information as "150 trees per hectare".

When plans are made to teach this unit, it is advisable to examine Unit S6, which continues the topic of measurement at a more advanced level. Furthermore, it is essential that measurement be a part of many other units in the implementation of the science curriculum. Hence, a concept such as volume will be reinforced repeatedly throughout the Intermediate Division and will not be just an isolated topic restricted to a small part of this unit. In fact, the topics within this unit may well be split up and taught within other units as the need arises.

Some of the work in the unit overlaps with sections of the mathematics courses for Grades 7 and 8. Teachers should, therefore, co-ordinate the work of science and mathematics so that the approaches in each reinforce and complement one another.

Note: Canada has recently adopted the upper case L as the symbol for litre. This also applies to prefixed units such as the millilitre (mL). The lower case l and the cursive or script ℓ will be seen for some time, but are to be gradually phased out.

E5.1: The need for quantitative description

Measurements often clarify a description. For instance, students may be asked to identify one of four wooden blocks or pieces of tape, all similar, but differing slightly in length. A similar exercise may be done with four beakers of water or four piles of sugar that differ slightly in volume or mass. A member of the set is not to be identified by its position. This illustrates the need for a quantitative description – the particular member is identified by its length, volume, mass, or some other measureable attribute. Various methods of describing things or substances quantitatively should be discussed, as well as some instances where comparisons cannot be made quantitatively, for example, joke A is three times as humorous as joke B, or is it?

Suggested terminology: *measurement, quantitative, qualitative.*

E5.2: Physical quantities and their units

A measureable characteristic or attribute is called a "physical quantity" and is made up of two parts, a number and a unit. The length, 6 m, of a ladder is a physical quantity. Students should be able to list a variety of different physical quantities, illustrate each by examples, and give the name and symbol for each unit. For example: the mass of a nickel is 5 g (grams).

Suggested terminology: *physical quantity, unit, symbol.*

E5.3: Linear units

Subtopics under the heading of linear units should include:

- the metre as the SI base unit of length or the primary linear unit in SI;
- the kilometre as a multiple;
- the decimetre, centimetre, and millimetre as submultiples;
- practical applications of these units;
- prefixes from “milli” to “mega”;
- simple conversions between common metric units of length.

m----- metre

km----- kilometre

dm-----decimetre

cm----- centimetre

mm----- millimetre

In general, these subtopics should be treated as a review of previous work, but tinged with some enrichment. The modern definition of the metre is not required, but historical references to the metre may be of interest. The meaning of SI multiples and submultiples of a primary unit should be indicated. Review the symbols for linear units and the rules governing their use.

Simple cost problems might be given. For example: what is the cost of this piece of cloth at \$4.95/m? Students should actually measure the length to the last full tenth of a metre and calculate the cost. The addition of provincial tax may be included by some students. Encourage the use of calculators if available.

Suggested terminology: *Système International, prefix, metre, kilometre, decimetre, centimetre, millimetre, base unit, multiple unit, submultiple unit.*

E5.4: Averaging

After estimating, students should use several different measurements to determine the length of an object whose length is irregular, such as a wooden board or a piece of canvas. The need to average several measurements should be shown. Another exercise is the measuring of the average thickness of a sheet of paper by measuring the thickness of a wad of 100 pages and then calculating from the result.

Suggested terminology: *average.*

E5.5: Rounding

This topic should be woven throughout the entire unit and carried into all other parts of the science program where any measurements and calculations are required.

No measurement is perfectly accurate. Examples of approximations and degree of accuracy may be discussed. For example: the height of the school is 6 m to the nearest metre or 6.3 m to the nearest tenth. Students should be able to apply the rules for rounding off a number in a physical quantity.

Note: When a 5, not followed by other non-zero digits is dropped, the rounded result must end in an even digit. For example, a length of 6.35 m is rounded up to 6.4 m, whereas a length of 6.25 m is rounded down to 6.2 m. When this procedure is used many times, the rounding up in some cases and down in others tend to compensate one another – hence, the rule.

Suggested terminology: *approximation, accuracy, “to the nearest . . .”, significant digit, rounding.*

E5.6: Area units

The following subtopics should be included:

- the square metre (m²) as the primary SI unit of area;
- multiple units – square hectometre (hm²), generally called a hectare (ha), square kilometre (km²);
- submultiple units – square decimetre (dm²), square centimetre (cm²), square millimetre (mm²);
- practical applications of these units, where appropriate.

Students should determine the areas of some surfaces by measuring and calculating. The correct form in writing solutions should be stressed.

Suggested terminology: *area, square metre, square kilometre, hectare, square centimetre.*

m²-----square metre

ha-----hectare

cm²---- square centimetre

E5.7: Volume units

The following subtopics should be included:

- the cubic metre (m^3) as the primary SI unit of volume;
- multiple units – cubic kilometre (km^3) (not common, but used to express the volume of oceans);
- submultiple units – cubic decimetre (dm^3), cubic centimetre (cm^3), litre (L), millilitre (mL);
- equivalents – $1 \text{ m}^3 = 1000 \text{ L}$
 $1 \text{ dm}^3 = 1 \text{ L}$
 $1 \text{ cm}^3 = 1 \text{ mL}$
- applications of volume units.

Students should be able to determine the volume of (a) a cuboid by measurement and calculation, (b) a liquid by means of a graduated cylinder, and (c) an irregularly shaped solid by displacement. Students should understand degree of accuracy, such as “to the nearest 10 mL”. To illustrate volume (or capacity) units, it is recommended that students be exposed to Canada’s standard kitchen measures:

small measures – 1, 2, 5, 15, 25 mL;

dry measures – 50, 125, 250 mL;

fluid measures : 250, 500, 1000 mL.

Sets of such measures may be very useful in the science room.

Suggested terminology: *volume, capacity, cubic metre, cubic decimetre, cubic centimetre, litre, millilitre, cuboid, graduated cylinder, meniscus, overflow can, displacement of water, standard kitchen measures.*

m^3	-----	cubic metre
dm^3	----	cubic decimetre
cm^3	----	cubic centimetre
L	-----	litre
mL	-----	millilitre

E5.8: Mass units

The following subtopics should be included:

- the kilogram (kg) as the primary unit of mass in SI;
- multiple units – megagram (Mg), tonne or metric ton (t);
- submultiple units – gram (g), milligram (mg);
- applications of mass units;
- the fact that 1 dm^3 or 1 L of water has a mass of 1 kg. (This is acceptable within the limits of accuracy attainable in the Intermediate Division.)

Students should be able to zero a balance and determine masses of solids and liquids fairly accurately. They should be able to measure out a required mass of a substance such as a powder or liquid.

Note: The word “weight” sometimes means “mass” and sometimes “force of gravity”. Because of this ambiguity, it is suggested that the word “mass” be used whenever mass is meant. If the word “weigh” is used in an instruction, it should imply “determine the mass of”.

Suggested terminology: *mass, kilogram, megagram, tonne, metric ton, gram, milligram, balance, zeroing a balance, rider.*

kg	-----	kilogram
t	-----	tonne
g	-----	gram

E5.9: Time units

The following subtopics should be included:

- the second (s) as the SI base unit of time;
- the existence of the millisecond (ms) and kilosecond (ks), although not used in this course;
- the minute (min), hour (h), and day (d) as non-metric multiples of the second, but permitted for use with SI;
- all-numeric times and dates;
- the difference between the time of day, such as 05:30, and a timed event such as 5 h 30 min or 5.5 h to run a long-distance event.

The verification of a scientific statement is an important feature of science. Students could be asked to test one or more of the following to see if they are true or false:

- If the length of a pendulum is doubled, the length of time for it to swing back and forth is also doubled.
- If the amplitude of a pendulum is halved, the length of time for it to swing back and forth is also halved.
- If the mass of the bob of a pendulum is tripled, its length of time to swing back and forth is shortened by at least 50%.

Note: Formal definitions of terms such as “period” and “amplitude” are not required. Such terms are a part of Vibrations and Waves (Unit S21).

It is not intended here to develop a quantitative relationship between the period and the length of a pendulum, but to have students design and implement their own strategy to test a given statement. Students should present conclusive arguments based on reliable data. Time may be saved by allowing different groups to verify the different statements above, all of which are false.

Suggested terminology: *time, second, minute, hour, day, pendulum, verification.*

s-----second
min-----minute
h-----hour
d-----day



E5.10: Temperature Units

The SI base unit of temperature is the kelvin, but it is not wise to introduce this unit in the Intermediate Division. An equivalent unit of temperature is the degree Celsius ($^{\circ}\text{C}$), which is permitted for use with SI. Students should be able to use a thermometer to find the temperatures in degrees Celsius of (a) the air in the room at different points, (b) an ice-water mixture, and (c) boiling water.

Suggested activity: Measure the temperature of 50 mL of cold water in one beaker. Measure the temperature of 50 mL of hot water in a second beaker. Just before mixing the cold and hot water, estimate their resulting temperature. Mix the two and verify the estimate. Discuss reasons for the following inequality: 50 mL of water at 20°C + 50 mL of water at 60°C $\neq$ 100 mL of water at 80°C . Why are the volumes added and the temperatures not? This may be left as an open-ended question to be reconsidered in another unit.

Suggested terminology: *temperature, degree Celsius, freezing point, boiling point.*

$^{\circ}\text{C}$ -----degree Celsius

E5.11: Rate of change

This concept involves the combination of two entirely different kinds of quantities, one of which is time. The rate at which an event occurs tells us how slowly or how quickly it happened. One or more of the following rates might be determined: (a) eating a banana in grams per second (g/s), (b) drinking some milk in millilitres per second (mL/s), (c) burning a piece of string in millimetres per second (mm/s) (*caution: students should light the string, blow out the flame, and allow the string to smoulder a measured distance previously marked on the string*), (d) heating some water in degrees Celsius per minute ($^{\circ}\text{C}/\text{min}$).

Students should also be able to determine their own speed in metres per second (m/s). The formula for speed, $v = d/t$, may be appropriate for some students at this stage, depending on the timing of the teaching of algebra. In this instance, the science and mathematics courses should be coordinated. A sentence equation, such as speed = distance divided by time, would be sufficient.

Since speed is also a topic in Unit S6, it is recommended that transposition of the formula $v = d/t$ to $t = d/v$ or $d = vt$ be omitted here. Relating kilometres per hour to metres per second is not required, but problems involving kilometres per hour may be relevant to students.

Suggested terminology: *rate of change, speed, compound units such as gram per second, metre per second, kilometre per hour.*

g/s-----gram per second
mL/s-----millilitre per second
mm/s-----millimetre per second
 $^{\circ}\text{C}/\text{min}$ degree Celsius per minute
m/s-----metre per second
km/h-----kilometre per hour

UNIT E6: PROPERTIES OF MATTER

In this core unit, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic in the unit.

Topics	Number of Periods
E6.1 Description of an object	1
E6.2 Description of a single substance	1
E6.3 *Properties, functions, and inferences	1
E6.4 *Qualitative and quantitative properties	1
E6.5 *Biological, chemical, and physical properties	1
E6.6 *Diversity of physical properties	5
E6.7 *Solid, liquid, and gas	1
E6.8 *Matter	1
E6.9 Non-matter	1
E6.10 Applications of matter based on properties	1
Review and evaluation	2
	16

Preamble

Through their study of this unit, students should develop an understanding of the concepts of "property", "property of matter", and "matter".

It is important that students become aware of the wide variety of properties that a substance or object may possess. "Physical properties of matter" are the central focus of the unit, and a knowledge of properties is useful:

- in comparing, identifying, and classifying substances;
- in selecting appropriate substances for practical applications;
- in further investigating the structure of matter.

In this unit, students will work with a variety of materials in order to examine a number of physical properties. This kind of activity involves such skills and processes as:

- measuring several properties of a single substance;
- comparing several substances with respect to a given property;
- devising methods of laboratory testing and of controlling variables; and
- verifying data related to properties of matter.

Students will consider classifications of matter (particularly into the three states: solid, liquid, and gas) and note that certain characteristics are common to all matter. The question of non-matter is posed so that students can identify what is matter and what is not.

This unit could naturally lead students to question why various kinds of matter have different properties and what matter is composed of. Other units could then take up these questions.

E6.1: Description of an object

Students may be asked to fully describe an object such as a pencil. All five senses should be used *where appropriate*. Students should recognize that any one object has a great variety of characteristics. They should be encouraged to note properties, functions, and inferences, and to answer questions such as the following: What are the dimensions, colours, materials, shapes, parts, and so on, that help describe the pencil? What is it used for – any other purpose besides writing? Who owns it? What do you think it cost? How was it made? Tell a Martian, who has never seen or used one, all about it. If time permits, students should also describe a living thing such as a worm.

E6.2: Description of a single substance

Students can fully describe an object that is made of a single substance, such as a bar of iron, a piece of ice, or a chunk of rock salt. (*Note: Students must not taste anything without permission from the teacher.*) Again, the inclusion of properties, functions, and inferences should be encouraged. Here, students should note that there is only one kind of substance – perhaps two in the case of ice as it melts into water.

E6.3: Properties, functions, and inferences

A property helps describe an object, a function indicates a use of the object, and an inference is a supposed fact about the object based on some evidence. Students can separate the properties, functions, and inferences that have been used in their descriptions. For example, an electric light bulb may be associated with the following properties, functions, and inferences:

properties – smooth, no taste, no smell, 11 cm long, pear-shaped, frosted, 40 W, fragile, hollow, made of glass and metal;

functions – used to give light, operates on 110 V circuit, can be used to warm an incubator or car motor;

inferences – made in Canada, was bought at Canadian Tire, was used in a home, probably in a bedroom.

Suggested terminology: *property, function, inference.*

E6.4: Qualitative and quantitative properties

Qualitative properties are not measurable; quantitative properties are measurable and are usually expressed by means of numbers and units. Students should classify the properties of an object into those that are qualitative and those that are quantitative. For example, a beaker has the following properties:

qualitative properties – transparent, solid, smooth, flat bottom, curved sides, fragile, open at top;

quantitative properties – 12 cm tall, 7 cm in diameter, walls are 2 mm thick, has a mass of 95 g, has a capacity of 400 mL.

Suggested terminology: *qualitative, quantitative.*

E6.5: Biological, chemical, and physical properties

Students can examine a number of items, such as an apple, some baking soda, a piece of chalk, a goldfish, a large nail, a potted plant, a rock, some salt, some vinegar (white), some water, and a wooden dowel. They can name those objects that are alive and state how they know that there is life. Properties that are based on the existence of life are

often called biological properties, and students should briefly list them. The point here is merely to acquaint students with the concept that a biological property is a property pertaining to life. More attention is given to this topic in Characteristics of Living Things (Unit E1).

Students should add about 1 mL of water to 2 mL of baking soda, and then add 1 mL of water to 2 mL of salt. This should be repeated using vinegar in the place of water. Canada's set of small kitchen measures (spoons) are useful for measuring small volumes. Here, students should list those combinations of substances that are chemically reactive, and should describe such substances as having a specific chemical property. Students can be shown a few chemical reactions at this stage to illustrate the concept of "chemical property". An in-depth treatment of this topic should be left for other units such as Chemical Change (Unit S2).

After this brief reference to biological and chemical properties, the focus of the rest of the unit is on physical properties. Properties such as length, area, volume, mass, temperature, hardness, elasticity, and conductivity are called physical properties. A number of these should be considered, discussed in simple terms, and illustrated with materials. See Topic E6.6.

Suggested terminology: *biological, chemical, physical property.*



E6.6: Diversity of physical properties

In this topic, the students' investigations are focused on the physical properties of substances. Students should become aware of a variety of physical properties that a substance may possess. Such properties can be used to identify, compare, and classify various substances. Not all of the suggested properties need be investigated, however. Only those that are most appropriate should be selected. Short, practical experiences and experiments with materials should be used to illustrate the various properties. The following are examples of questions that might stimulate students to consider various properties:

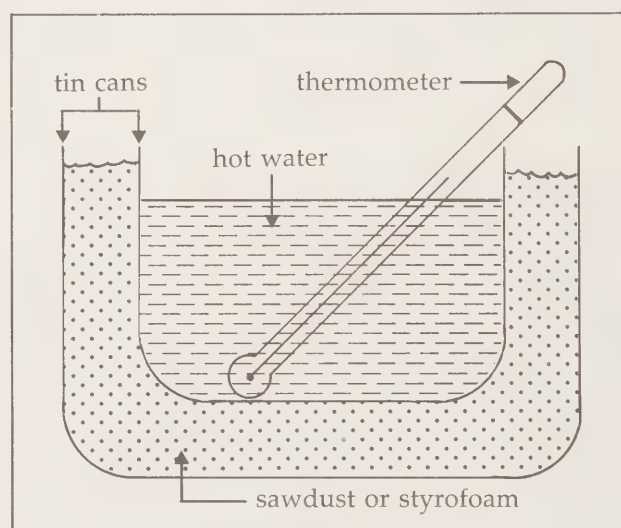
- Does everything have length, width, height? Does oil? Does air?
- When is area an important attribute?
- Which has the greater volume, 100 g of iron or 100 g of wood?
- Do large masses always have large volumes?
- Which warms up faster, water or oil? (In this case, should equal volumes, equal masses, or both be compared?) *Caution: Do not overheat oil; merely warm it.*
- How can a sponge become denser? (No problems on density should be given here; in fact, the definition of density is not needed in this unit. Reference should be made only to one substance at a time and density should be related to compactness — as the volume decreases, the substance becomes denser.)
- Which bounces higher, a rubber or a steel ball? Which is more elastic, a short rubber band or a long one (a good exercise in percentage or ratio and proportion)?
- Does salt dissolve as easily as sugar?
- Does ice melt as easily as wax? *Caution: The ice and the wax should be melted by placing them in hot water.*
- Of two rocks, which has the greater hardness?
- Of two magnets, which is the stronger?
- Are two blades of grass from the same lawn equally green?



- Which is more transparent, lucite or glass? (Perhaps there are different kinds of glass in the school building that may be tested.)
- Is ice cream a solid or a liquid?
- Which is more effective in preventing heat loss from a can of hot water, a layer of sawdust or a layer of styrofoam?
- In an extension cord, what is metallic and what is non-metallic?

Students should have the opportunity to devise some investigations of their own and to produce good reports based on reliable data. As time permits, this topic will provide valuable experience in different laboratory techniques, for example:

- heating substances safely;
- taking temperatures carefully (and graphing results);
- deciding whether certain measures should be accurate or approximate;
- timing events if quantitative results are desired;
- equalizing conditions where needed (for example, identical inner and outer cans placed in similar positions for equal time periods when comparing the insulating qualities of sawdust and styrofoam);



- comparing relative values (for example, the length of a stretched short rubber band compared to its original length and the length of a stretched long rubber band compared to its original length);
- taking the average of several results or trials;
- devising alternative techniques, for example, measuring the strength of a magnet by counting the number of nails it will support; finding the number of centimetres a magnet will stretch a strong rubber band to which is attached a keeper; or determining the number of newtons of force required to pull the keeper off the magnet (for the measurement of forces in newtons, see Unit E3: Force and Energy);
- constructing a graph, for example, graphing the times and temperatures when heating oil and water or melting ice and wax.

Some of the properties suggested by this topic are covered in more detail in other units. Here, the point is to expose students to a broad but shallow coverage of a variety of physical properties, such as length, area, volume, mass, temperature, density (in the sense of dense, denser, densest), elasticity, solubility, rate of melting, hardness, magnetism and non-magnetism, colour, transparency, state, conductivity, metallic and non-metallic.

Suggested terminology (choose from the following): *length, area, volume, mass, temperature, density, elastic, inelastic, soluble, insoluble, magnetic, non-magnetic, hardness, transparent, opaque, solid, liquid, fluid, conductor, insulator, metallic, non-metallic.*

E6.7: Solid, liquid, and gas

Students can be asked to identify major subdivisions, categories, or classes of matter. A wide variety of these could be encouraged; for example: living/non-living; metallic/non-metallic; pure substances/mixtures; edible/inedible; solids/liquids/gases; float in water/sink in water; soluble/insoluble; transparent/translucent/opaque. An interesting way to present this is to have about twenty items on a table and to have students actually classify the substances and objects into various sets. The names of the items could also be written on the chalkboard, but this is less interesting. A third possibility is to supply the students with cards showing the pictures or names of items and to have them sort the cards.

The students' attention should be directed to the states of matter. They can devise a chart to show the distinctions among the three states, using the following or similar expressions: fills container, gases, liquids, shape, solids, stable, states, varies with container, volume. The advantages of organizing knowledge into a chart such as the following could be discussed:

States	Shape	Volume
solids	stable	stable
liquids	varies with container	stable
gases	varies with container	fills container

The state of such substances as far as certain temperatures is debatable. For many substances, a knowledge of their melting and boiling points is useful to identify them or to separate them from a mixture. Such ideas may be briefly discussed. Some of this will be dealt with in Separation of Substances (Unit S18).

Suggested terminology: *states of matter, solid, liquid, gas.*

E6.8: Matter

By now, students should be able to identify the difference between an object and a substance. They should know that "matter" is the general term for all substances and materials. When asked how the amount of matter might be determined, they will probably include the idea of finding the volume and mass.

The use of the word "weight" in this instance should be avoided. It is reasonable to define matter as something that has mass and occupies space. The following questions can be asked:

- Is air matter or non-matter?
- How can this question be answered?
- Can anyone design a test?

The fact that air has mass and occupies space should be shown. "Mass", in turn, can be defined as "a measure of the quantity of matter in a substance or object, regardless of the amount of space it may occupy". *Note: Conservation of mass is a topic in Chemical Change (Unit S2) and Measurement (Unit S6).*

Suggested terminology: *matter, mass.*

E6.9: Non-matter

Students can be asked the following questions:

- Is there such a thing as non-matter?
- Do the following have any mass:
 - a) a beam of light from a flashlight;
 - b) the heat radiating from a hot metal ball;
 - c) the magnetic field around a magnet;
 - d) the sound from a loudspeaker;
 - e) a vacuum?

These questions are difficult to answer experimentally and perhaps should be left open-ended. However "energy" will be a common word for the students, and it may be claimed, again without evidence at this stage, that energy is not matter – although matter can certainly have energy. Energy is dealt with elsewhere, for example, in Force and Energy (Unit E3).

Suggested terminology: *non-matter, energy, vacuum.*

E6.10: Applications of matter based on properties

Students might list examples of substances such as copper, wood, alcohol, leather, baking soda, water, fibreglass, salt, and cement. Applications of the substances are then named, and for each application corresponding properties of the substance are identified. For example:

Substance: wood

Application: diving board

Related properties: 4 m × 50 cm × 5 cm, solid, elastic

UNIT E7: ADAPTATION AND BEHAVIOUR

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
E7.1 Inherited behaviour	2
E7.2 *Tropisms and taxes	3
E7.3 *Learned behaviour	4
E7.4 *Protective mechanisms	3
E7.5 *Body language	3
Review and evaluation	2

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Preamble

The study of adaptation and behaviour could cover an in-depth treatment of the physiological and biochemical nature of the receptor-activity mechanisms in organisms. It has been included here in order to increase student awareness of the variety of animal and plant behaviours and to provide a wide range of simple, observational investigations that students can do either individually or in small groups. In this unit, attention should be given to forming hypotheses and making inferences about the reasons for certain behaviours under given circumstances. The tentative nature of such experimental results should be made clear to students: laboratory exercises indicate only what an organism does in the laboratory and not necessarily what it will do in its natural surroundings.

Behaviour normally involves a reaction on the part of the whole organism to some external stimulus or group of stimuli. It is important, therefore, to carefully define the question to be investigated. It is also necessary to decide which variables are dependent and which are experimental, that is, which ones are to be kept constant as students investigate inter-relationships. Where applicable, teachers should make every effort to provide suitable analogies to adolescent behaviour.

The following suggestions offer a variety of questions that teachers may ask their students. The unit can be used in a meaningful way to help students develop positive and successful social behaviours and, in this process, a healthy self-image.

E7.1: Inherited behaviour

We have all inherited some traits or characteristics from our families. Can this be illustrated for members of the families of some of the students? Interviews with relatives could be undertaken, and students could list some characteristics of people in general that allow humans to survive as a separate species.

Not everyone reacts in a similar way to the same stimulus. A number of variations noticed in the reaction of different people to a particular incident such as a power failure may be given. Is there any reasonable explanation for this variation in behaviour? Are such reactions purely instinctive in humans? Is such behaviour hereditary?

Here is another way of considering behaviour. Each year during the fall, waterfowl from Northern Canada migrate to more southern latitudes. Often the males leave first, then the females, and finally the immature birds. How do the young birds reach their southerly destination without ever having been there before?

Suggested terminology: *behaviour, hereditary, instinctive, migratory.*

E7.2: Tropisms and taxes

Tropisms are reactions of sessile organisms, usually plants, to external stimuli. Taxes are reactions of motile organisms, usually protists and animals, to external stimuli. Students can observe a number of reactions, and can make some hypotheses concerning these reactions, of selected protists, plants, and animals (including humans), to light (white and coloured) and darkness, hot temperatures, water (or lack of it), nutrients, chemicals, and sound waves. This presents a good opportunity to develop the process of manipulating and controlling variables. *Note: Caution should be exercised when testing vertebrates. (See Appendix C.)*

Students can test their hypotheses and then draw inferences where possible. For example: Was there any variation in the results among different members of the same species? Did different students have diverse results with the same species? Can causes for these differences be suggested? Did all parts of an organism appear to react in the same way to the stimulus in an investigation? Is this surprising? Students should seek to form some generalizations from their inferences even though there may be some variation in the responses. They should also state how reliable they think their generalizations are. Teachers can help to ensure a random selection of organisms for the investigations involving tropisms and taxes.

Suggested terminology: *tropisms, taxes, stimulus, hypothesis, inference, generalization.*

E7.3: Learned behaviour

Behaviour is the result of "nature and nurture", that is, inherited factors and learned behaviours in response to the environment. The most simple kind of learned behaviour is called imprinting; it is seen in very young pets. The following questions may be raised:

- What are the roles, either real or apparent, of the younger and older members of an imprinting association? Suggest some reasons for the actions of the younger members.
- Domestic fowl cannot be as clearly imprinted as wild birds. Is there a simple explanation?
- Mimicry, as seen in the monarch and viceroy butterflies and in the coral and king snakes, has a useful purpose. What is the purpose?
- Many birds, such as evening grosbeaks, are nomadic in their habits. What does the term “nomadic” mean and how does it differ from “migratory”?

Many young people model their behaviour patterns after television stars or a favourite relative, adult, or peer. Students might give some examples of this type of behaviour (including mannerisms) that can be detected in people known to them. Why is it that this type of behaviour is quite variable in its intensity and duration among different people?

Psychologists such as Pavlov and Skinner have conducted some intriguing investigations on a wide variety of animals. Students can read about their work on conditioning – that is, programming a similar response to different stimuli – and on trial-and-error learning. They may cite instances in everyday life where the conclusions of Pavlov and Skinner on animal behaviour are being used to alter human behaviour. They can offer their personal reactions to this kind of learning environment and, perhaps, they can use mealworms to test their own ideas on conditioning. A visit by a dog trainer to the class could be useful in expanding this topic.

Students may be asked to suggest some of the kinds of human behaviour our society feels necessary. How do students learn about these appropriate behaviours? Are some behaviours harder to learn than others? From whom is it easiest to learn these social behaviours? Are they learned once, forever, or is some repetition necessary? Adolescents can be helped, both in and out of the classroom, to learn behaviours that can enhance their chances of being happy, healthy, and personally successful. These important ideas should be a part of the content of this topic.

Suggested terminology: *imprinting, conditioning.*

E7.4: Protective mechanisms

In order to survive, every organism must maintain itself in spite of environmental factors that sometimes cause it to function less ably than under normal conditions. Most birds and aquatic animals are darker on top and lighter on the underside of the body. How does this colouration help protect such animals?

Ruffed grouse have the unique habit of burying themselves under the surface of the snow during certain types of winter weather. In what type of weather does this behaviour occur? What are the characteristics of the snow and what possible hazards are there for the grouse in this occasional behaviour?

Many animals that are prey for predators exhibit herding, flocking, or schooling behaviours. Why do they do this? What kind of animal exhibits this type of behaviour and who are its predators? Does this behaviour help the individual or the group? When do students exhibit similar behaviour and under what circumstances? Compare this behaviour to a “stag line” at an adolescent dance. Students can also investigate protective mechanisms in such animals as the ptarmigan, the fawn, and the angler fish.

Different organisms react quite differently to the presence of danger. Some remain motionless; others run, hide, or change colour. Students can investigate this type of protective behaviour to see if it changes when the organism’s natural environment is altered.

Most plants, protists, and invertebrates are unable to move rapidly enough to get away from inclement weather conditions. If time permits, the dormancy procedures for selected species of plants, protists, and invertebrates can be compared as they relate to temperature, light, and water excesses or deficiencies. Hibernation is a special type of dormancy. Under what conditions is this state induced? Students can explore the conditions under which states of dormancy cease and the organism regains normal activity.

Suggested terminology: *predator, dormancy, hibernation.*

E7.5: Body language

Students may be asked whether they have ever noticed that a dog, when away from its home and chased by another, larger dog, will do some of the following:

- run homewards with its tail lowered and ears down;
- roll over on its back with its feet up;
- turn and face its opponent, bristle its mane, and bare its fangs;
- turn sideways and back off.

What are the signals that the dog’s body language is trying to convey to the chaser?

It may be worth while to expose students to some of the findings of Karl Frick’s study of honeybee communication through sound, body language, and the sampling of nectar.

Body language can vary from a slight movement to great, enthusiastic locomotion. Students might be asked the following questions: What types of body language do you use? When and why do you employ them? How effective are they on you and on others? Is it possible to convey the wrong message through body language? Students could discuss how they can improve this part of their social behaviour.

Suggested terminology: *body language, signal.*

UNIT E8: ASTRONOMY

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
E8.1 Historical development	1
E8.2 Orbital motion	1
E8.3 *The earth	1
E8.4 *The moon	2
E8.5 *The planets	3
E8.6 *The sun	2
E8.7 *The stars	2
E8.8 Other celestial bodies	1
E8.9 Astronomical instruments	1
Review and evaluation	2
	16

Preamble

The purpose of this unit is not to outline an entire course of study in the science of astronomy, but rather to suggest a number of subtopics within the nine major topics that students could investigate. It should not be assumed that students will cover every subtopic. Rather, students should be encouraged to proceed along independent lines while in pursuit of a subtopic that interests them.

Although not specifically mentioned in the teaching suggestions, it is assumed, throughout this unit, that students will be encouraged to carry out, as far as is reasonable, observations at home. In this regard, powerful telescopes are not essential, since much can be seen with the naked eye. However, a good pair of binoculars would be a definite asset.

Since many observations may extend over an interval of perhaps a month (for example, observation of the moon's phases or of planetary motion), it is conceivable that a group of students might be involved in a number of activities simultaneously.

A good supply of resource material is necessary, and audio-visual aids should be used extensively, since the concepts of size, distance, and time, when applied to astronomy, are staggering to the imagination.

As students proceed through this unit, emphasis should be placed on the development of library research and reporting skills. In addition, opportunities are provided here for the development of observation and recording skills.

E8.1: Historical development

The science of astronomy has its roots in the distant past when people needed to know when to sow, when to reap, and when to conduct religious rituals. Students might briefly examine the ancient's view of the night sky, particularly the views held by the Egyptians and the Greeks. The careful observations made by the Chinese and the Mayas might also be mentioned.

Each era has produced geniuses who have addressed themselves to problems in astronomy. A study of some of these people and their contributions might include the following:

- Copernicus contradicted the earth-centred Ptolemaic theory with his explanation of both the earth's rotation on its axis and its revolution around the sun.
- Galileo was the first to observe the heavens through a telescope and, in so doing, supported the Copernican theory.
- Kepler formulated the laws of planetary motion.
- Newton formulated the laws of gravitation, created the first reflecting telescope, and discovered that light can be separated into a spectrum.
- Einstein formulated the theory of relativity to explain the form of the universe.
- Hubble formulated theories of the universe's origin by examining distant galaxies.

Other contributors to the science of astronomy that could be studied include Hipparchus, Tycho Brahe, and Sir William Herschel.

Suggested terminology: *Ptolemaic theory, Copernican theory.*

E8.2: Orbital motion

Although the universe is an ordered system, and the motions of the planets are a reflection of that order, it was not until the work of Kepler and Newton that planetary orbits were understood and described. Through observations and an examination of charts or diagrams that illustrate the planets' orbits, students might be made aware of the following:

- All the planets revolve in the same direction around the sun (counter-clockwise when viewed from above).
- The speeds of the planets in their orbits decrease as their distances from the sun increase. For example, Mercury's average orbital speed is 48 km/s; Earth's is 30 km/s; Saturn's is 10 km/s; and Pluto's is 5 km/s.
- The shape of each planet's orbit is an ellipse with the sun at one focus. The point in a planet's orbit farthest from the sun is termed the *aphelion*, the point closest to the sun is called the *perihelion*. Students might practise drawing variously shaped ellipses to illustrate these features.
- The path or band along which the planets move through the sky, as seen from the earth, is termed the *ecliptic*, and the background constellations through which they move are called the *zodiac*.

Suggested terminology: *revolve, orbit, ellipse, focus, aphelion, perihelion, ecliptic, zodiac.*

E8.3: The earth

The earth is of interest to astronomers since it is the only planet about which there is abundant knowledge. Students may compare and contrast the earth with other planets in the solar system using the following information:

a) *Some orbital characteristics:*

- mean distance from sun – 150 000 000 km or 150 Gm (gigametres) or 1 AU (astronomical unit);
- length of year – 365 d (approximately);
- rotation time (on its own axis) – 24 h (approximately);
- seasonal changes occur because of the tilt of the earth's axis;
- one large moon revolves around the earth.

b) *Some physical characteristics:*

- diameter at the equator – 12 683 km;
- atmosphere – composed of 78% nitrogen, 21% oxygen, 0.04% carbon dioxide, and less than 1% argon and other gases (approximately);
- has a strong magnetic field;
- surface temperature ranges from -88°C to 58°C;
- water covers 71% of the planet's surface;
- crust shows evidence of movement – continental drift, mountain building, and erosion;
- possesses abundant and varied life forms.

Suggested terminology: *rotation, mean distance.*



E8.4: The moon

Any study of the moon or planets should be based on current information, since knowledge of the solar system has greatly increased in the past decade.

A study of the moon may be conducted under a number of headings, some of which are suggested here:

- the moon in myth and legend – including popular superstitions;
- phases – observations over several nights to note and account for changing phases;
- eclipses – the mechanics of lunar eclipses;
- surface features – may include a study of crater formation, maria, rills, mountains, the lunar environment;
- lunar exploration – function and findings of the Apollo landings and conditions necessary for the astronaut's survival.

Suggested terminology: *lunar eclipse, phase, maria, rill.*

E8.5: The planets

Many previous ideas concerning the planets have become outdated in this decade. Information gained from the Pioneer, Mariner, and Viking space probes will doubtless alter, even further, many of our presently held concepts. Students should be encouraged to locate the planets in the night sky and, if possible, to observe them through a telescope.

Unifying themes, for example, the search for life, might be employed to study the planets. How suitable is each planet to support life as we know it?

A comparative study of the planets might include orbital characteristics and physical characteristics (see Topic E8.3). Attention should be drawn to the recent findings of the Mariner, Pioneer, and Viking series of planetary probes. The draft of a student report on one planet done in this manner could include such material as the following:

Mercury

a) *Some orbital characteristics:*

- mean distance from sun – 58 000 000 km or 58 Gm;
- length of year – 88 earth days;
- rotation time – 59 earth days.

b) *Some physical characteristics:*

- diameter at equator – 4850 km;
- atmosphere – none detected;
- surface temperature – ranges from -150°C to 425°C;
- surface features – resembles the moon, heavily cratered, evidence of lava flows, large cliffs, relatively flat areas (plains), surface possibly covered with a layer of dust, no evidence of water now or in the past;
- no known moons.

E8.6: The sun

While the sun is unique in the solar system, it is not an unusual star. It is what astronomers term a yellow-dwarf; a member of the most numerous kind of stars. Although it dominates the solar system and provides this planet with life-sustaining energy, its interest to astronomers lies in the fact that it is the only star near enough to show a surface that can be studied.

Note: In any solar studies, students should be cautioned never to look directly at the sun, since irreparable damage to the eyes could result.

The sun's surface may be studied telescopically by projecting its image on a piece of cardboard. A study of the sun may be conducted under a number of headings, such as the following:

- the sun's surface – including a study of sunspots, granulations, solar flares, prominences, temperatures, rotation;
- the sun's interior – energy-producing reactions, elements found in the interior, temperatures;
- effects on the earth – energy supply, tides, northern lights;
- solar eclipse – mechanics of solar eclipses, corona, importance of solar eclipses to astronomers;
- life cycle of the sun – possible origins, development, life expectancy.

Suggested terminology: *sunspot, granulation, solar flare, prominence, corona, solar eclipse, umbra, penumbra.*

E8.7: The stars

To begin to understand the universe, students must try to fathom the immensities of the times, sizes, and distances that are involved. Although no one can fully comprehend these concepts, an appreciation may be gained by reducing them to the commonplace. For example, if the thickness of this page represents the distance from the earth to the sun (150 000 000 km), then the distance to the nearest star is represented by a stack of paper 22 m high. The diameter of our galaxy is a 500 km stack, and the edge of the known universe is not reached until the pile of paper is 50 000 000 km high!

Since astronomical distances are so great, ordinary standardized measurement is of little use, since the units are too small. To overcome this difficulty astronomers use (a) the astronomical unit: the distance from the sun to the earth (150 000 000 km), or (b) the light year: the distance light travels in one year at the rate of 300 000 km/s, about 10 trillion kilometres or 10 Pm (petametres). The distance to the nearest star is about 4.3 light years or roughly 40 trillion kilometres or 40 Pm. *Note: The prefix "peta" denotes 10^{15} .*

The stars may be studied under a variety of headings, such as:

- star classification – students should note that all visible stars have definite colours that are related to their temperatures;
- size – diagrams or models can be used to illustrate the sizes of various stars compared to that of the sun;
- the constellations – an examination of the night sky to locate easily identifiable constellations (use of the Big Dipper as a starting point); use of star charts and planispheres;
- unusual stars – binary stars, variables, neutron stars, novae, supernovae, red giants, white dwarfs;
- star names – including common names and classification within constellations.

Suggested terminology: *light year, planisphere, constellation, binary stars, neutron star, nova, supernova, astronomical unit.*

E8.8: Other celestial bodies

This topic may be grouped in three ways:

- objects within the solar system;
- objects outside the solar system but within our galaxy;
- objects outside our galaxy.

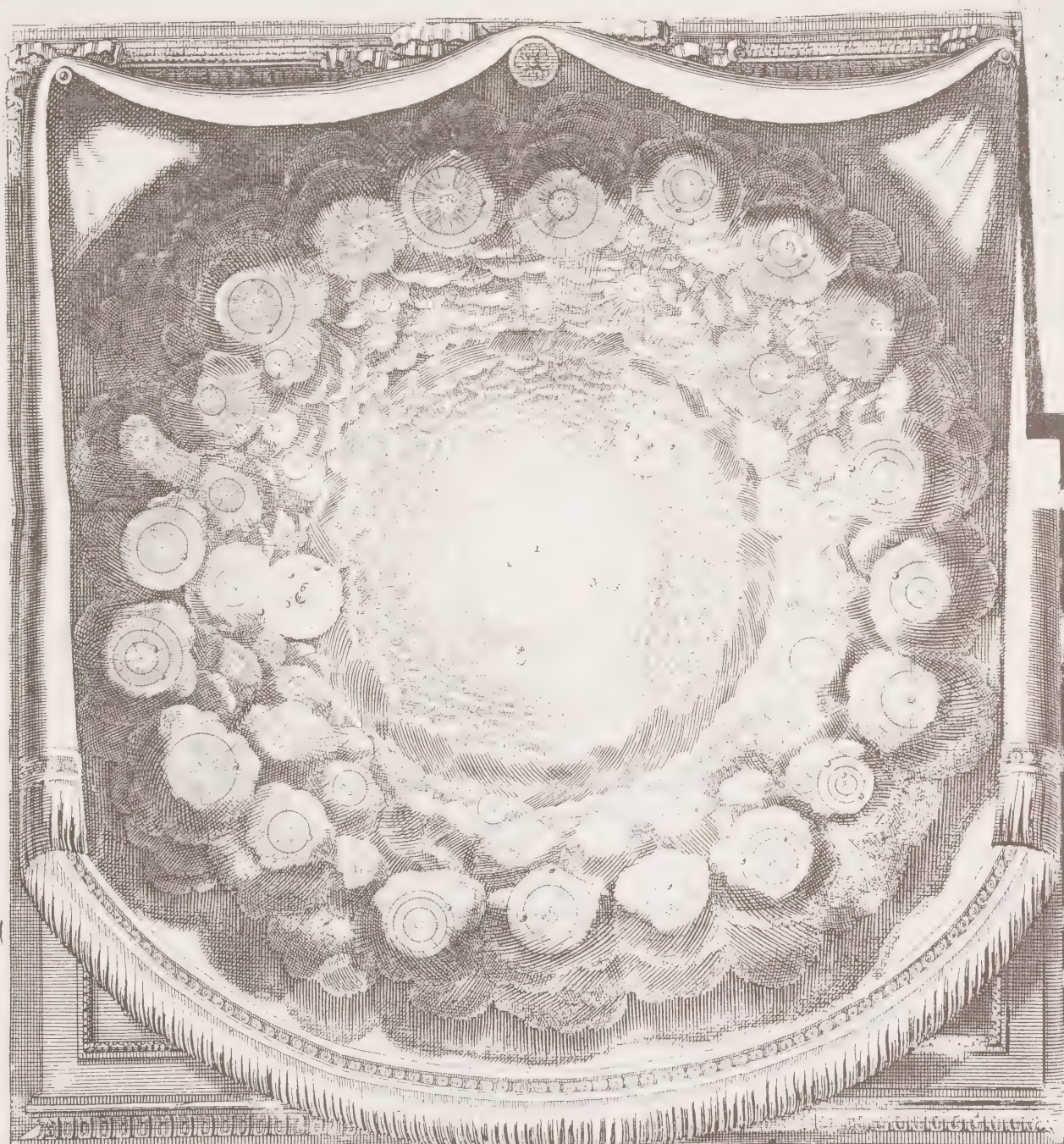
The first subtopic includes a study of meteors and comets. Students may report on meteor composition and well-known meteor showers. A study on comets might include reporting on various reappearing comets, their orbits, and their structures. The second subtopic includes a study of star clusters (open and globular) and nebulae. The third subtopic includes a study of the galaxies including, for example, types, distances, and the Milky Way.

Suggested terminology: *galaxy, nebula, meteor, comet, Milky Way.*

E8.9: Astronomical instruments

Students should have an opportunity to examine the two basic types of telescopes (reflectors and refractors) to note their optical qualities and their respective advantages and disadvantages. A study of Light (Unit E12) should be a prerequisite to a detailed examination of optical instruments. A brief examination of other instruments used in astronomy, such as radio telescopes and spectrometers, might be conducted.

Suggested terminology: *reflecting telescope, refracting telescope, spectrometer.*



1. Mercure · 2. Venus · 3. La Terre · 4. Mars · 5. Jupiter · 6. Saturne ·
 1. Dôlmar Sculpteur

ENTRETIENS

SUR

LA PLURALITÉ
 DES MONDES.



VOUS voulez, Mon-
 sieur, que je vous ren-
 de un compte exact
 de la manière dont j'ai passé

UNIT E9: FORESTRY RE-SOURCES

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
E9.1 *Northern boreal forest	4
E9.2 *Great Lakes – St. Lawrence regional forest	4
E9.3 *Forest products	3
E9.4 Forest land use	3
E9.5 Forests, soil, and water	1
Review and evaluation	2
	17

Preamble

Forests are one of Canada’s greatest resources. Over a quarter of a million Canadians are employed in timber harvest and in the manufacture of forest products. In Ontario alone, there are sixty million hectares of forest land. Thousands of hectares of forests with their lakes, streams, and waterfalls have been set aside as parks and preserves where their natural treasures can be appreciated as part of our heritage. Forests can also be considered as vast laboratories for student and scientist alike.

In this unit, students will study the characteristics of both the coniferous and temperate deciduous forest. It is suggested that students develop an understanding and appreciation of various forest products and the alternatives facing man in the wise use of forest land. This unit should be considered for inclusion in a course of study if students have access to a “forest laboratory”. When teaching this unit, refer to Interdependence of Living Things (Unit E4).

Science teachers should be careful to discuss this unit with geography teachers in order to avoid undue overlap between courses. Some topics, such as E9.4: Forest land use, may be covered adequately in geography courses.

E9.1: Northern boreal forest

Students should become familiar with some of the features of the northern boreal forest. They should ask themselves a series of questions related to the forest and, where feasible, try to discover some answers or explanations. The following background information and questions will help students in their investigations.

In Ontario, a coniferous forest lies between the tundra and the northern extremities of the Great Lakes. It is believed that centuries ago a massive ice sheet scraped away top soil in this region and produced a mosaic of lakes and swamps. The soil of the northern boreal forest is shallow, water-logged, acidic, and nutrient-deficient. How do such characteristics affect spring flooding, bacterial action, and the presence of earthworms in the soil?

The plant life of the boreal forest must cope with poor soil, low temperatures, and limited rainfall. Why do conifers thrive in this environment? Why are the shape and structure of such coniferous trees as the tamarack, white spruce, black spruce, and white cedar ideally suited for northern winters? Students can observe, identify, and study such species to find answers to these questions.

The following descriptions of common evergreens will be useful in helping to identify them:

- Scotch pine – needles are about 5 cm long and in clusters of two;
- jack pine – needles are about 2.5 cm long and spread apart in clusters of two;
- spruce – needles are half-round, half-flat, and are positioned all the way around the twig;
- balsam – needles are flat, roughly 2.5 cm long, and appear in two rows on the side of the twig;
- tamarack – needles are fine, rather long, and appear in clusters;
- white cedar – leaf and twig are in a flat arrangement.

Students can also study the effects of the local environment on particular species. For example, the jack pine is common in dry or fire-marked areas, whereas the tamarack or larch is frequent in moist areas. Why is the vegetation of a dry forest floor restricted to ferns, mosses, and a few herbs?

The structure and behaviour patterns of animals such as the fox, wolf, and moose have adapted to survive the cold winters of the boreal forest. Students could describe and explain such adaptations. They can study the hibernation of the woodchuck and the chipmunk. What are the characteristics of the birds that feed on the limited choice of food in a coniferous forest? Why are forest areas dominated by one or two tree species that are especially vulnerable to attacks by such insects as the sawfly and the spruce budworm?

Suggested terminology: *coniferous, boreal, species, hibernation.*

E9.2: Great Lakes — St. Lawrence regional forest

Deciduous trees such as the beech and maple begin to invade the southeastern fringe of the boreal forest in ever-increasing numbers until the mixed growth gradually blends into a temperate deciduous (deciduous-coniferous) forest. Students living in such an area may wish to record local environmental data to account for such forest vegetation. Factors that could be considered are: annual precipitation, temperature ranges, relative humidity, soil structure, and the amount of light.

Students can perform identification studies on such common deciduous trees as the maple (hard, silver, red, Manitoba), ash, oak (red, white), basswood, elm, beech, willow, aspen (trembling, large-toothed), pine (red, white), hemlock, and red cedar. A study of Dutch elm disease could be undertaken. Students can explain why the forest is a "bank" for the storage of energy and water. The following questions could be posed to help students investigate the role of animals in such a forest:

- How are some animals adapted for tree-dwelling?
- Why are deciduous trees a major source of food for animals?
- What groups of insects are most destructive to such a forest?

- How have larger carnivores of the deciduous forest suffered from human intrusion?

Suggested terminology: *deciduous*, *carnivore*.

E9.3: Forest products

As a tree grows year by year, it produces countless tiny fibres all firmly bound together. Interestingly enough, this material (wood) has properties that no other material has. Students can list some characteristic properties of wood and perhaps also some special properties of several kinds of wood.

It takes about four hundred trees to furnish all the wood products that the average person uses in a lifetime. Most of the paper used in the world is made from wood. Students can find out how many tonnes (1 t = 1000 kg) of newsprint their local newspaper uses each year. They can also investigate how paper is manufactured from pulpwood if there is a paper mill close by.

Wood is composed of cellulose, lignin, and water. Cellulose can be separated chemically from lignin and then made into many synthetic materials such as photographic film, cellophane, viscose, and rayon. Students can investigate these and other materials made from cellulose that they use everyday. How is lignin used in the manufacture of plastics? Students can investigate other forest products such as oils, resins, acids, and dyes.

Suggested terminology: *cellulose*, *lignin*.



E9.4: Forest land use

Present land-use patterns in Ontario include trees for many purposes. They are used:

- as orchards, wind rows, woodlots, and for soil stabilization on agricultural land;
- for shade and beauty, as buffers against noise and curbs for visual and air pollution, and for soil retention in urban settlements;
- for shade, beauty, wildlife management, and camping sites in forest parks;
- as a raw resource for fibre, fuel, and food.

This topic is intended to give students the opportunity of surveying most of the possible "tree uses" in their immediate locality at a practical level. Students could also investigate alternatives for the use of tree-land and come to some general understanding of the potential conflicts and compatibilities that arise as a result of human use of available land. Alternative land uses that could be discussed and investigated are:

- agricultural versus resource use of the land;
- treed-agricultural versus recreational use of the land;
- recreational use versus settlement;
- urban settlement and transportation versus resource use;
- recreational versus resource use;
- treed-agricultural use versus urban settlement and transportation.

Each of these six possibilities could be considered separately using local examples. The advantages and disadvantages of each alternative in a conflicting-use situation could be explored, discussed, and debated. An objective approach to problem-solving should be emphasized. Attention should also be drawn to the importance of such primary industry as agriculture and forestry in the economy of the province and the interrelationships among industry, commerce, and tourism.

E9.5: Forests, soil, and water

The roots of trees grow deep into the ground and anchor the soil, particularly on hillsides and mountains. Leaves and decaying branches make a cover for the soil, which soaks up water like a sponge. (How is the water in the soil returned to the atmosphere?) Thus, forests not only produce lumber and pulpwood, but also reduce erosion and control floods. Students should understand the relationship between the wise use of forests and soil stabilization.

We manage our forests to serve our needs. Students can become actively involved in tree-planting and reforestation. The reasons for tree-planting are numerous:

- Trees around a spring or stream protect the source of water supply.
- Trees provide windbreaks for farm buildings, roads, and fields.
- Erosion on steep, sandy, rocky land and gullies is prevented by tree planting.
- Trees can provide a crop on stony, hilly, rocky, wet, or inaccessible land.

In the planning for tree-planting students should remember that the tree species selected must be adapted to the soil and that the use of the plantation governs the selection of species and the method of planting. It is suggested that contact be made with the local office of the Ministry of Natural Resources for help with this kind of activity.



UNIT E10: HEAT AND TEMPERATURE

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
E10.1 Sources of heat	1
E10.2 *Expansion of metals	2
E10.3 *Expansion of water	1
E10.4 *Expansion of air	1
E10.5 *Meaning of temperature	1
E10.6 *Conduction	1.5
E10.7 *Convection	1.5
E10.8 Radiation	1
E10.9 *Melting of ice	1
E10.10 Boiling of water	1
E10.11 Kinetic molecular theory	1
Review and evaluation	2
	15

Preamble

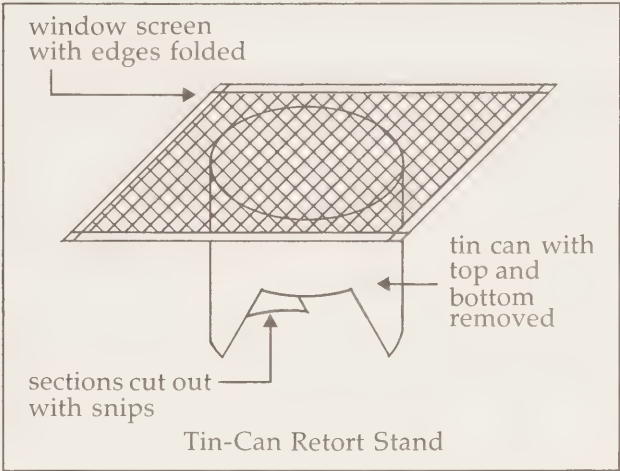
This unit lends itself to the development of experimental skills. Most of the work can be covered through the use of experiments, allowing students to discover for themselves some of the physical principles related to heat. With some teacher guidance, students should be encouraged to design their own experiments. Because of the practical nature of this unit, the teacher should emphasize the applications of scientific phenomena to everyday life related to heat transfer, expansion, and changes of state.

Heat is a form of energy, and this needs to be stressed throughout this study. It becomes especially important when dealing with the particle nature of matter and the response of particles to the addition and removal of heat. This is explained through the kinetic molecular theory.

The following suggestions regarding equipment may be helpful:

- Candles, alcohol burners, high-wattage light bulbs, hot plates, or even hot radiators can act as heat sources. *Caution: Place candles and alcohol burners on aluminum-foil plates or asbestos pads to reduce the hazard of fire. Hair and loose clothing must be tied back and not allowed to come near open flames. See Appendix B.*

- Ice cubes or snow in the winter can be used as a cooling agent. If a temperature lower than the freezing point of water is needed, ordinary salt added to ice will lower the temperature to about -10°C . The evaporation of alcohol or even water will lower temperatures to some extent.
- Support stands can be fashioned from large tin cans. (See the accompanying diagram.)



- Tin cans and Pyrex containers can be used for heating and cooling liquids.
- *Students must not insert glass tubing into, or remove it from, rubber stoppers without supervision by the teacher.* It would be advisable to have the tubing and stoppers prepared in advance in order to reduce the possibility of accidents and to save class time.

Throughout this unit, students will learn facts about heat transfer, expansion due to heat, and some ideas related to the use of thermometers and to changes of state. These concepts will then be brought together when students consider the kinetic molecular theory.

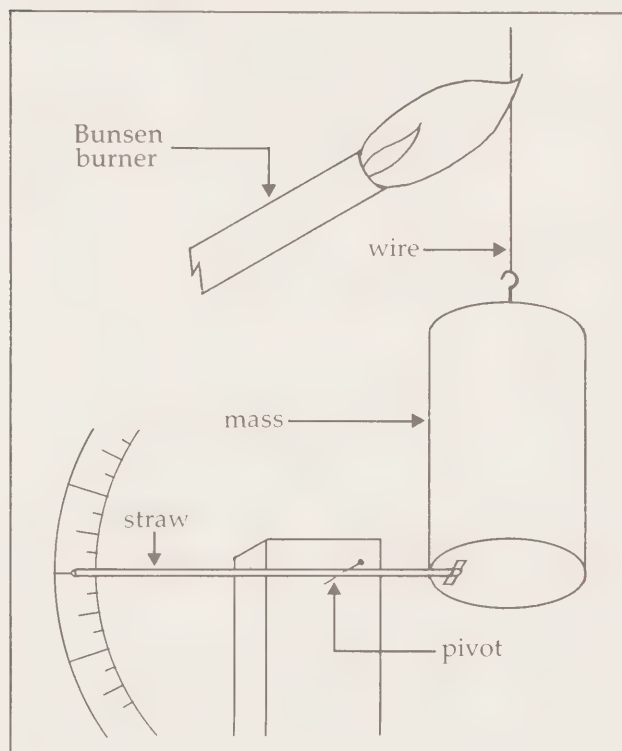
E10.1: Sources of heat

The sun is our main source of heat. Students should be asked to name a variety of other heat sources. A number of short activities could be conducted to show how mechanical action, such as friction, percussion, compression, and distortion, will produce heat. Compression can be illustrated by means of a bicycle pump. Distortion can be demonstrated by repeatedly bending a strip of metal or a thick piece of wire until it becomes quite warm. The important thing to stress here is that energy is required to produce heat. Electric and chemical energy can also be changed to heat energy. Students could name a number of appliances that convert electric energy to heat. They may also mix plaster of Paris with water and observe that heat is released as the plaster hardens. How can light or radiant energy be used to start a fire? A student might be asked to demonstrate this. Nuclear energy may also be mentioned.

Suggested terminology: *friction, percussion, compression, distortion.*

E10.2: Expansion of metals

Suggested activity: a 50 cm length of bare copper or iron wire is hung from a retort stand with a 500 g mass attached at the lower end. The wire is gently and evenly heated for a short period of time. It is then allowed to cool. Careful observation of the length of the wire should be made both when it is cool and when it is hot. The movement of the mass may be magnified by taping one end of a drinking straw to its bottom surface. The straw is permitted to pivot about a pin which acts as a fulcrum placed near the mass. The free end of the straw is observed as the wire is heated and cooled.



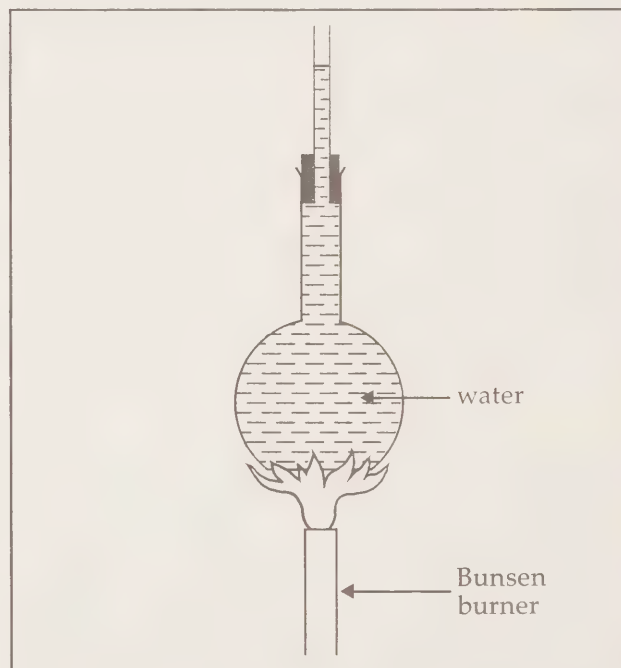
Expansion and contraction due to heat may also be demonstrated by the “ball and ring” apparatus and by a compound bar made of a bimetallic strip. Do all metals expand the same amount when heated through the same temperature interval? What evidence is there for the answer to this question?

A discussion of the importance of thermal expansion and contraction of metals and other solids should follow, illustrated with practical examples. Thermostats and dial-type thermometers are good examples of the unequal rate of expansion of metals.

Suggested terminology: *expansion, contraction, thermostat, bimetallic strip.*

E10.3: Expansion of water

The main problem is to make a rather slight expansion of water clearly visible. An activity to demonstrate this is relatively easy to conduct and students may have ideas as to how this can be shown. Given some hints, they may come up with the need to have a small cross-sectional area (narrow bore tubing) through which the water is to expand, and colouring in the water in order to improve the observable effect. The opportunity to offer suggestions in this way about the design of an experiment is an important part of science, even if the teacher provides hints and some of the apparatus that may be required to conduct the investigation. The operation and construction of the thermometer should be discussed briefly.



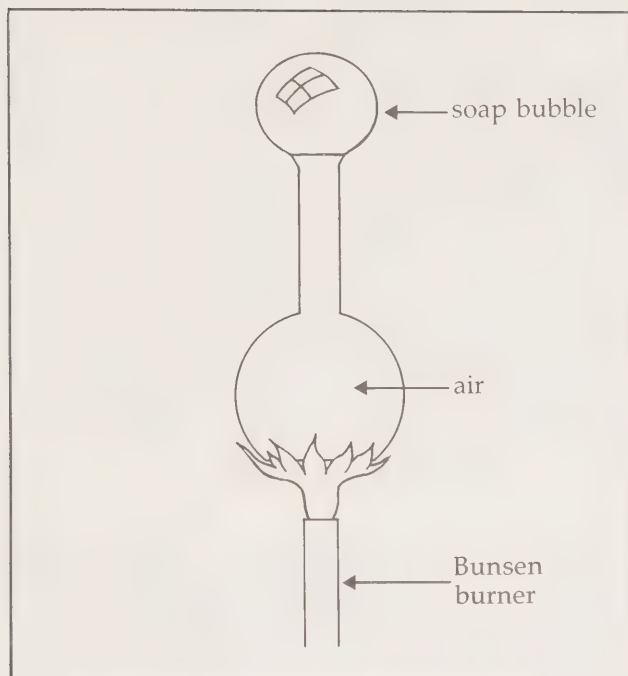
Note: See the cautions in the preamble regarding the use of glass tubing and heating.

Suggested terminology: *thermometer, bore.*

E10.4: Expansion of air

The apparatus for the previous experiment on the expansion of water may also be used to demonstrate the expansion of air. Students may suggest how this can be done. Other techniques may be suggested, such as using a flask of air with a soap bubble or a balloon over its mouth. Cooling as well as heating should be applied. What can be concluded from this experiment about the force exerted by the air against the inside of a closed container if the temperature of the air rises? How does this affect the amount of air one would put in tires during the summer and during the winter?

A theoretical issue may be raised with students at this point. They have had some evidence that different metals expand at different rates. What about liquids? Perhaps the thermal expansion of different liquids could be demonstrated by the



teacher. Flasks of the same size with fine-bore tubing could be put into a basin of hot water and then into a basin of ice water, or vice versa. Different liquids will be found to expand at different rates. What about gases? The natural conclusion is that they should behave in the same manner as different solids and liquids. In fact, many different gases expand at about the same rate. The need to have experimental evidence before rushing to conclusions should be impressed on students. This should be left open-ended, because there would not be time to prove this issue with respect to gases. However, this kind of process – forming a hypothesis and then checking to see if it is valid – could be well illustrated in this topic.

Students could set up an air thermometer and observe it over a period of several days, noting its advantages and disadvantages.

E10.5: Meaning of temperature

A man has half a pail of luke-warm water (25°C) with which he wishes to wash a bicycle. He asks his son and daughter to add more hot water to make the water in the pail hot. His son brings out a cup of boiling water (100°C), but his daughter brings out half a pail of very hot water (80°C). Which will the father choose, and why? Such a problem, perhaps illustrated with a real example, may be used to show the meaning of temperature as a measure of the level of heat but not of the quantity of heat.

Students should be able to use a thermometer effectively and understand the Celsius scale. (The kelvin, although a base unit of SI, is not needed in the Intermediate Division.) Students should know the freezing and boiling points of water (0°C and 100°C); normal body temperature (37°C); room temperature (20°C); that 10°C is cool, 20°C is comfortable, and 30°C is hot; and that -10°C is good for skating, -20°C is rather cold, and -30°C is very cold.

If time permits, a brief study might be made of different kinds of thermometers such as candy, clinical, oven, outdoor, wall, aquarium, soil, gas, and bimetallic thermometers. Some of these may be borrowed from home. Students could also make their own coloured-water thermometers, if desired.

Suggested terminology: *temperature, degree Celsius, boiling point, freezing point, clinical thermometer.*

E10.6: Conduction

Suggested activity: Wax pieces can be placed on a metal curtain rod or coat hanger at equal intervals. Holding one end of the rod, a student heats the other end. Why do the wax pieces drop off? Do all solids conduct heat equally? How could this be tested?

Students can design and perform an experiment to test the conductivity of different solids. Commercially made conductometers can also be used. Does water conduct heat? This could be demonstrated by pushing a small ice cube to the bottom of a test tube of water and holding it there. The water near the top of the test tube is then heated. If the ice melts rapidly, the water is probably a good conductor. Practical applications of good heat conduction and insulation should be discussed. The fact that still air is a good insulator and is used between storm windows and trapped in home insulation in attics, walls, and so on, should be stressed.

Suggested terminology: *conduction, conductivity, conductor, insulator.*

E10.7: Convection

In the previous topic, students learned that water and air are generally poor conductors. How is heat transferred in liquids and gases? A small crystal of bluestone or potassium permanganate is dropped into a beaker of still water near the side of the beaker, which is then heated gently just below the crystal. This will demonstrate convection currents. (Hint: If you use potassium permanganate, place a glass tube into the beaker of water and drop the small crystal down the tube; when the crystal reaches the bottom, put your finger over the top of the tube and lift out the water above the crystal.)

Convection in gases can be demonstrated by using a smoke box, a candle, and smoke paper, or just a large jar with a cardboard divider hanging from its mouth. The candle should be placed in one-half of the container. Why does the smoke rise in one half and fall in the other half? Hot air does not rise of its own accord, since normally the force of gravity is pulling it downwards. Cold air (or water) is denser and falls to the bottom forcing the warmer air (or water) upwards. Why is cold air denser than hot air?

An excellent application of convection is a hot-air or hot-water heating system. One of these could be discussed using simplified diagrams for the explanation.

Suggested terminology: *convection, convection currents.*

E10.8: Radiation

Although the space between the earth and sun is “empty” (a vacuum), heat travels to us through 150 000 000 km of space. Is the heat conducted? Is it convected? What is the name of this type of heat transfer? Students can hold their hands above, below, and to one side of light bulbs. Again, what is this type of heat transfer called? What method of heat transfer would only be felt below the light bulb? *Note: The method of heat transmission — that of radiant energy — cannot be explained at this stage.* How is it different from conduction and convection? Examples of items that radiate heat should be listed: for example, the sun; any fire such as a campfire; electric heaters, toasters, and clothes dryers; light bulbs; hot-water tanks and pipes; our homes in the winter; our bodies; a car engine; and molten steel in industry.

If time permits, the following questions may be discussed or investigated:

- Does a dull, black object radiate heat more readily than a shiny, white one?
- Do dull, black clothes, roofs, and other surfaces absorb radiant heat more readily than smooth, white ones?
- What is a solar collector and what is it used for?
- What is a radiometer and what kinds of energy sources activate it?
- What examples of absorption of radiation are essential to human life?

Suggested terminology: *radiation, absorption.*

E10.9: Melting of ice

The objective here is to establish the melting point of ice as 0°C and to investigate whether there is a temperature change in an ice-water mixture as heat is added to melt the ice. Put another way, the following hypothesis may be proposed. “Whenever a substance is heated in a flame, its temperature rises, that is, it obviously gets hotter.” Students should try this out with an ice-water mixture, carefully taking the temperature every minute until all the ice has melted. This could take a rather long time, so a suitable amount of ice and water should be used. The results should be graphed on a time-temperature graph. What conclusion do the students reach concerning the hypothesis? If a hypothesis is proven incorrect, was it a “bad” one? Does heating the ice-water raise its temperature? What does the heat energy do to the ice?

There will probably not be enough time to cool water down until it solidifies, so the reverse process, that of freezing, will have to be discussed, rather than demonstrated. Students will have to be told that water freezes at 0°C , the same temperature at which the ice melts.

Suggested terminology: *change of state, melting, freezing, solidification.*

E10.10: Boiling of water

Time may not permit students to plot a full change-of-state curve to illustrate the temperatures before and during boiling. However, if time is available to carry out this activity, students must be cautioned about *tying back loose hair and clothing when working with open flames*. They could note that the temperature of boiling water does not change over several minutes, even though it is being heated. What is the heat energy doing to the boiling water? Discuss briefly the reverse process, that of condensation. Evaporation and condensation in the atmosphere can occur at temperatures other than 100°C . This may also be included in this topic.

Suggested terminology: *boiling, vaporization, evaporation, condensation.*



E10.11: Kinetic molecular theory

How can heat travel from one point to the next and so on along a piece of metal? Why does the metal expand so that these points become slightly farther apart? Why does a solid like ice break down into liquid water and later into gaseous steam when heated? Why does expansion lower the density of a substance? Why is there no temperature change during a change of state? Why is a liquid so “weak” compared to a solid? Why is a gas so “flimsy”? Why are solids generally better conductors of heat than gases (although this is by no means proven in this topic)? Of what is matter composed? Through a series of questions, students should be able to devise explanations and create postulates that could build into a theory. Their theory may then be compared to the kinetic molecular theory.

Suggested terminology: *theory, kinetic, molecule, kinetic molecular theory.*

UNIT E11: LIFE CYCLES

In this core unit, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

Of the topics marked with a dagger (†), at least two are obligatory.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic in the unit.

Topics	Number of Periods
E11.1 *Comparison of asexual and sexual reproduction	2
E11.2 *Examples of asexual reproduction	2
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Preamble

This unit provides students with an opportunity to develop a generalized concept of reproduction, a topic of special interest and significance to students entering adolescence. Central investigations in this unit serve to illustrate the basic differences between asexual and sexual reproduction. Some common examples of each type of reproduction are then examined by the students. The concept of “cycle” is introduced and applied to schematic diagrams, illustrating both the cyclic nature of the life of organisms and the basic requirement of sexual reproduction, namely, the union of a sperm and an egg to form a zygote. The remainder of the unit involves the study of the life cycles of a number of representative plants and animals. To conclude this unit, students can examine the means by which people have used their knowledge of reproduction to produce new species, to control injurious insects, and, by selective breeding, to produce more desirable stock.

E11.1: Comparison of asexual and sexual reproduction

Since every organism has a finite existence, reproduction is necessary if a species of plant or animal life is to continue. Reproduction may be regarded as the ability to produce another living thing that is similar to the originating species (see Topic E1.4 for further information). Both plants and animals show asexual and sexual reproduction. It is suggested that the difference between “asexual” and “sexual” be defined first; the consideration of examples would then follow.

Asexual reproduction. The green alga *spirogyra* may be used as a representative organism to establish basic differences between sexual and asexual reproduction. Students should examine cells that are in the process of dividing. This may be done through the use of the microscope, films, or prepared slides. This method of reproduction is a type of cell division called fission. The two new cells so formed are daughter cells and the cell from which they originate is termed the parent cell. Reproduction arising from the cell or cells of a single parent, that is, where no uniting of cells takes place, is said to be asexual. Asexual reproduction is common among simple organisms.

Sexual reproduction. Students may examine prepared slides of conjugating *spirogyra*. They can observe the ladder-shaped strands (filaments) and note the evidence that two cells have joined to form a single cell. This process occurs when single strands of *spirogyra* lie close together. Adjacent cells develop protuberances which grow and come into contact. The cell walls then dissolve and cell material from one cell flows into the other. The new cell so formed is termed a zygote and will, if conditions for growth are suitable, develop into a new filament. This form of sexual reproduction, where two similar cells unite, is termed conjugation. Conjugation is a simple form of sexual reproduction, since a new cell is created by the union of the cellular contents from two parent cells.

Suggested terminology: *asexual, sexual, zygote, conjugation, fission, parent cell.*

E11.2: Examples of asexual reproduction

Examples of asexual reproduction include cell division or fission, budding, and spore formation. To illustrate these types of reproduction, students can use prepared specimens and audio-visual materials.

Fission. Students can examine, under the microscope, prepared slides of a *paramecium* or an *amoeba* undergoing fission. They can note the changes that take place in the cell structures during this process.

Budding. Students may examine prepared slides or diagrams of yeast or a hydra (an aquatic multi-cellular animal) for an example of asexual reproduction that is known as budding. The one-celled yeast develops buds at the surface of the cell. Each bud increases in size until it breaks off and forms a new organism. A hydra sometimes develops buds on its sides. The cells in each bud increase in number and eventually form a new hydra, which then breaks off and begins an independent existence.

Spore formation. Students might collect a variety of common fungi (mushrooms, tree fungi, bread mould). Using a microscope, students can examine the spores from the reproductive organs of these fungi. Since the spores develop from the cells of one parent, this form of reproduction is asexual.

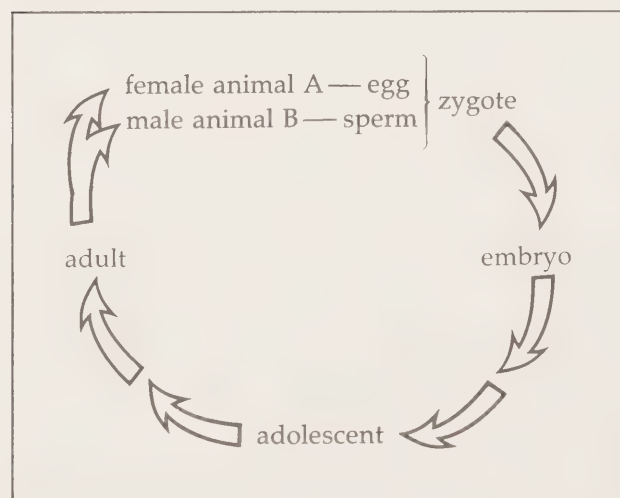
Suggested terminology: *fission, budding, spore, paramecium, amoeba, yeast, hydra, fungi, mould mushroom.*

E11.3: Examples of sexual reproduction

Before examining various types of sexual reproduction and, subsequently, the life cycles of certain organisms, it would be instructive to determine the students' concept of "cycle". This may be done by questioning students on how they use words such as bicycle, tricycle, and water cycle. Have students examine what these terms have in common, that is, the idea of circular motion or of something that repeats itself. This knowledge may be applied to the sections that follow.

Key steps in animal reproduction can be shown in the following diagram. See also Topics E11.6 and E11.8 for examples of this type of reproduction.

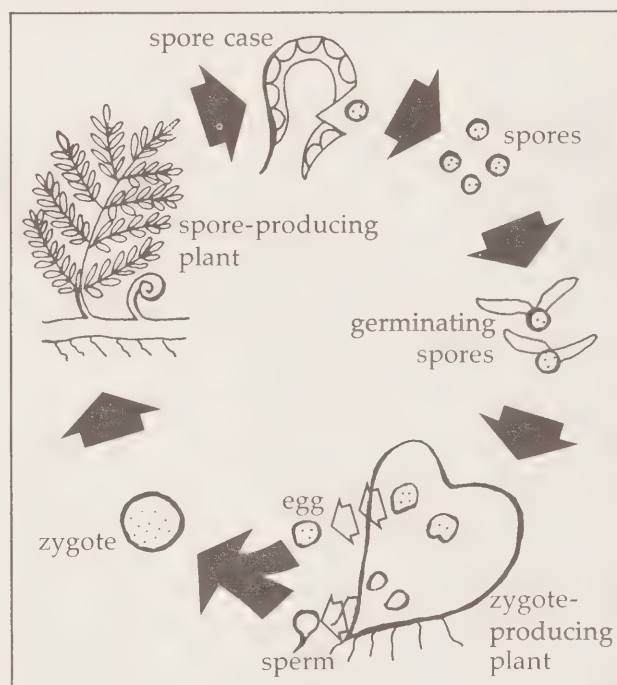
Suggested terminology: *life cycle, egg, sperm, zygote, embryo.*



E11.4: Life cycle of a fern

This topic is not intended to develop a detailed knowledge of plant structures, but rather to illustrate the increasing complexity of reproduction exhibited by higher plants. The life cycle of a fern represents a type of sexual reproduction termed "alternation of generations". Students can observe a fern plant for spore-producing structures. They can try to germinate some fern spores. With the aid of diagrams and audio-visual material, students can observe and describe the life cycle of a fern as it is illustrated in the following diagram:

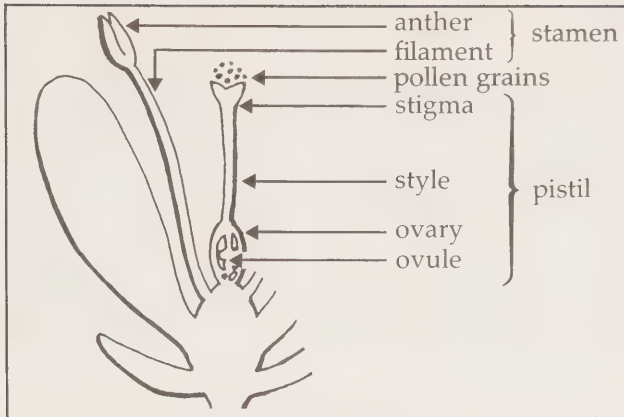
Suggested terminology: *alternation of generations.*



E11.5: Life cycle of a seed-bearing plant

Although any seed-bearing plant may be used as an example, the following comments pertain to flowering plants. Flowers contain the reproductive organs of flowering plants. In order to understand such a life cycle, students can begin by examining the parts of several complete flowers to identify the organs of reproduction — stamens, anthers and filaments, pistils, stigmas, styles, ovaries. See the accompanying diagram of the reproductive organs of a flower.

Students can shake several mature flowers over a clean piece of paper and gather the pollen grains. They can observe them through a microscope to note the variety of their size and shape. They can locate the stamens and examine them with a hand lens to observe the pollen. Similarly, an examination may be made of the stigmas to note the grains of pollen. Students can suggest hypotheses to ex-



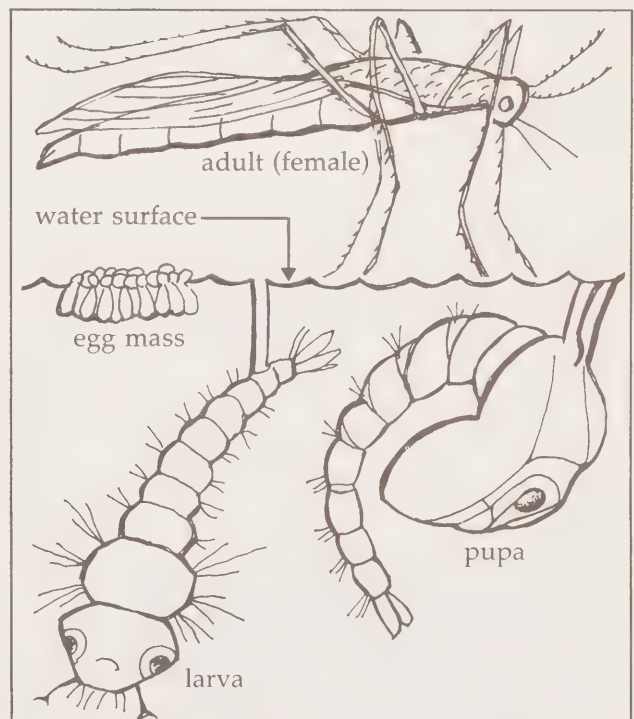
E11.6: Life cycle of an earthworm

Earthworms are bisexual, or hermaphroditic. Since the male and female reproductive organs cannot be easily observed in a dissection, labelled diagrams would be a useful aid. The following questions may be helpful in developing this topic: Can an earthworm's eggs be fertilized by its own sperm? How may the creation of the slime tube be described? What is its function? How does the slime tube become a capsule and eventually a cocoon? How do fertilized eggs develop into tiny earthworms? What is known of the habitat, habits, and economic importance of earthworms?

Suggested terminology: *hermaphroditic, slime tube, capsule, cocoon.*

E11.7: Life cycle of insects

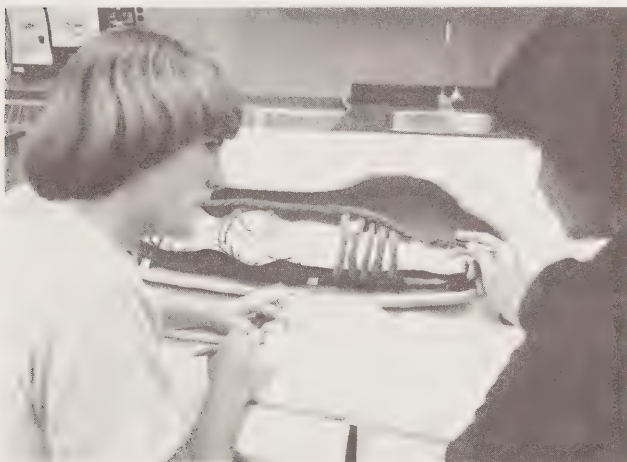
The mosquito. The life cycle of the mosquito exhibits egg, larva, pupa, and adult stages and can be described as complete metamorphosis. The accompanying diagram shows these stages:



plain how the pollen could be transported to this position. The process of moving pollen from the anther to the pistil is termed pollination. This is the first step in the sexual reproduction of flowering plants. Various means by which pollen is transferred to the stigma can be discussed.

By means of prepared slides or films, students can examine a vertical cross-section of the pistil. They can examine the style and ovary to observe the pollen tubes growing towards and into the ovary. Fertilization takes place when the pollen tube, which contains sperm, enters the ovary and a sperm unites with an egg contained in an ovule. The egg, thus fertilized, is termed a zygote. The zygote, in turn, grows to become an embryo which, with its food and protective coat, becomes the seed. Students may examine a number of seeds to observe their various structures. Once germinated, seeds can produce sexually mature plants that in turn will undergo pollination and fertilization, and thereby continue the life cycle.

Suggested terminology: *stamen, anther, filament, pistil, stigma, style, ovary, pollination, pollen tube, seed, fertilization, ovule, zygote, pollen grains.*



The development of the students' observational skills is considered important in this and other life-cycle investigations. The following points can be considered when designing an activity or discussion about the life cycle of the mosquito:

- **Adult:** A day or two after entering the adult stage mosquitoes mate. The male deposits sperm cells inside the female and fertilization takes place within her body.
- **Egg stage:** The female lays between 200 and 400 cartridge-shaped eggs, which take the form of a raft on the surface of quiet, shallow water. These eggs hatch, often the same day they are laid, to form larvae.
- **Larva stage:** The larvae (wigglers) float upside down just under the surface of the water. Students should observe specimens under a hand lens to note the body parts. In about one week these larvae change into pupae.
- **Pupa stage:** The pupae are active and float about, suspended below the surface of the water. An examination of pupae under a hand lens will reveal body parts. In about two to four days, adult mosquitoes emerge from the pupae and, when mature, are ready to mate and begin the life cycle again.

The grasshopper. The life cycle of the grasshopper exhibits incomplete metamorphosis, since this development includes only egg, nymph, and adult stages. The following activities and considerations are important in the study of the life cycle of the grasshopper:

- **Adult:** Students should examine the adult female grasshopper to note the ovipositor. The grasshopper eggs are fertilized during the summer months by male insects while the eggs are still in the female's body.
- **Egg:** During late summer or early fall, the female digs a hole in the ground with her ovipositor and deposits therein a number of slender white eggs. These fertilized eggs hatch into nymphs the following spring.
- **Nymph:** Newly hatched grasshoppers are termed nymphs. Students should describe the structure of a nymph. Nymphs grow until their exoskeletons become too small, at which point they shed (or moult) their exoskeletons. The nymphs continue to grow in this manner and moult five times altogether before becoming adults ready to mate and carry on the life cycle.

Suggested terminology: *metamorphosis, larva, pupa, ovipositor, nymph, exoskeleton.*

E11.8: Life cycle of a frog

In order to study the life cycle of a frog, students may examine prepared, dissected specimens of male and female frogs to observe the reproductive organs of both sexes. Frog eggs can be obtained to allow students to study the life cycle.

Female frogs lay thousands of unfertilized eggs in still water during the spring. Male frogs deposit sperm cells in the water near the eggs, and fertilization takes place. Students can describe the appearance of fertilized frog eggs.

The tadpole. Students can observe the following development of features in a tadpole:

- Newly hatched tadpoles lack eyes and a mouth, but have exterior gills.
- Older tadpoles have eyes and mouth, but lack exterior gills.
- The hind legs appear.
- The front legs appear.
- The tail diminishes, and the mouth size increases.
- The tadpole then resembles a young frog.

In concluding this unit, teachers may wish to discuss briefly the ways in which humans have applied their knowledge of plant and animal reproduction. For example, we have created new species of useful plants by controlled pollination; selective breedings of animals have produced more desirable stock; in insect control, sterilization is achieved by irradiating adults; and we spread oil on water to kill mosquitoes in the larva stage. Other applications may be listed.

Suggested terminology: *tadpole, sterilization, breeding, irradiation.*

Ontario Ministry of Natural Resources



UNIT E12: LIGHT

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
E12.1 *Rectilinear propagation of light	2
E12.2 *Transparent, translucent, and opaque materials	1
E12.3 *Reflection	3
E12.4 *Refraction	3
E12.5 Lenses	2
E12.6 The spectrum	2
Review and evaluation	2
	15

Preamble

This unit is concerned with the study of light and what can happen to it on its way from a source to the eye. Some fundamental characteristics of light will be examined and patterns of behaviour of light will be established through experiments. Under controlled circumstances, students will, thus, be able to predict the behaviour of light.

It should be noted that before beginning this unit students should have a basic understanding of angles. Therefore, it is essential that the science and mathematics courses be co-ordinated in this area.

A light source in which the emergent light can be controlled by varying the light beams according to position, shape, and number would be most helpful in this unit.

As follow-ups to this unit, students might explore the workings of a camera, the structure of the eye, or the influence of colour on emotions.

This unit should be a preparation for Geometric Optics (Unit S14), which should be carefully read so that undesirable overlap is avoided.

E12.1: Rectilinear propagation of light

Most students have noticed that a beam of light passing through a crack in a door or from a projector appears to travel in a straight line. (These beams of light can be seen because they illuminate dust particles in the air.)

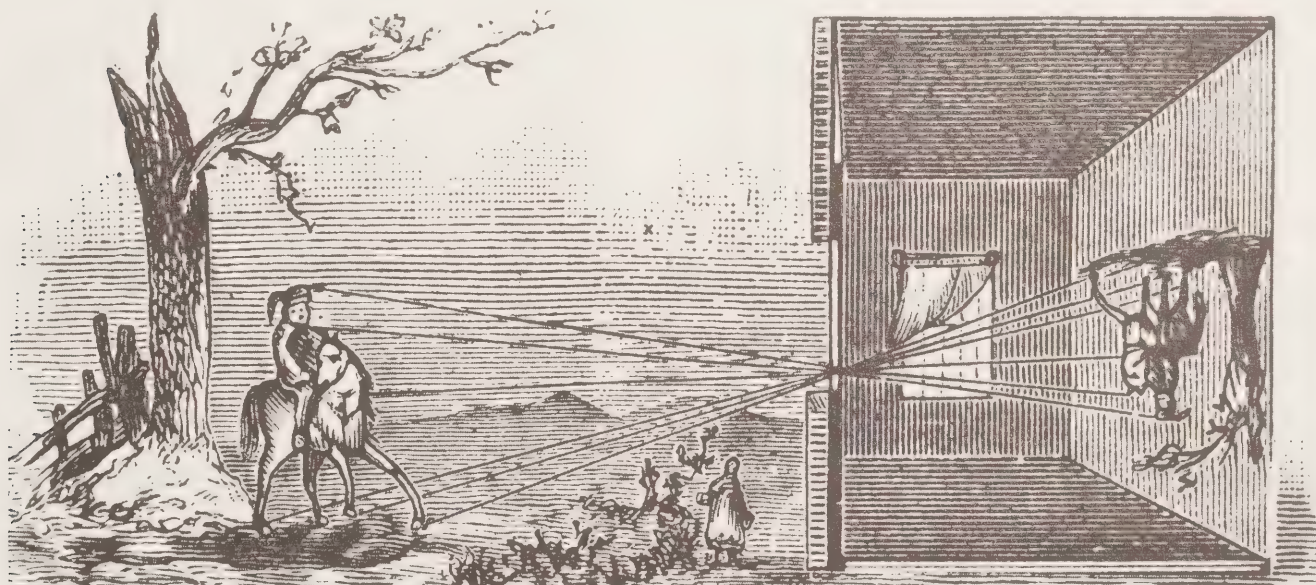
The pinhole camera is a simple application of the rectilinear propagation of light. To make a pinhole camera, cut out one end of a cardboard box and cover the opposite end of the box with a piece of wax paper. Make a hole in the centre of the opposite end of the box with a darning needle. A candle flame or light bulb can be placed a short distance in front of the hole.

Students may be asked questions such as the following:

- What can be noticed about the image?
- How does this show that light travels in straight lines?
- What happens when the object is brought closer to the camera?

Since this activity must be carried out in a darkened room, the students might note the problems to be considered in making a room pitch black.

Suggested terminology: *rectilinear propagation*, *pinhole camera*.



E12.2: Transparent, translucent, and opaque materials

A variety of transparent, translucent, and opaque materials can be made available to the students in order that they may investigate the following:

- Will light pass through all of the materials?
- What happens to light when it meets and/or passes through these various materials?
- Which materials will, and which will not, allow light to pass through?

Some fabrics are more transparent than others. Is this kind of transparency due to holes in the material or due to the nature of the substance of which the fibre is made? Some students may wish to examine this point. Applications to drapery materials, window blinds, clothing, and so on may be considered.

Suggested terminology: *transparent, translucent, opaque.*

E12.3: Reflection

Before taking up the law of reflection, students should first become familiar with the terms “incidence” and “reflection”. They might place a plane mirror on a desk or on a floor where a beam of light (sunlight will do) will strike it and be reflected. A drinking straw is then placed upright at the spot where the beam strikes the mirror (along the normal). Students can now compare the angle made by the incident beam and the straw with the angle made by the reflected beam and the straw.

Students might then observe examples of the law of reflection by drawing a dotted line on a piece of paper with a ruler. A solid straight line is drawn from it at any angle. A small plane mirror is then placed upright at the point where the two lines meet and turned until the reflection of the dotted line is in line with the real dotted line (the normal). By looking into the mirror, the students can now line up one edge of a ruler with the reflection of the solid straight line. This new line is drawn with a pencil, and the angles on each side of the broken line can be measured with a protractor. Arrows should be added to the first solid line (the incident ray) and to this new line (the reflected ray) to show the direction in which the light travels. This experiment can be repeated several times, changing the size of the angle each time. Would curved and irregular-surfaced mirrors work the same way as does a plane mirror? Students might apply the law of reflection in building a periscope or copying drawings by reflection.

Suggested terminology: *incident ray, reflected ray, normal, angle of incidence, angle of reflection.*

E12.4: Refraction

In order to understand the concept of refraction, students might first investigate what happens to light when it passes from one transparent medium through to another. The students might attempt to strike a penny at the bottom of an aquarium with a straw or to look at a pencil through a thick piece of glass held at an oblique angle to their line of sight. They could then examine a more controlled situation using a light source, a single-slit endplate, and a transparent viewing-block. A diagram should illustrate the path of the ray of light from the source through the viewing-block and beyond. What happens to the ray of light? Without having to make many measurements or to draw a lot of diagrams, students should investigate what happens as the angle of incidence changes from, say, 0° to 20° to 40° to 60° .

Suggested terminology: *incident ray, refracted ray, emergent ray.*

E12.5: Lenses

Since refraction finds a useful application in lenses, the above experiment can be repeated using concave and convex lenses in place of the viewing-block. The type of lenses used in eyeglasses for near-sighted and far-sighted eyes, hand lenses, microscopes, or telescopes might also be investigated and explained, as time permits. Explanations should be relatively simple.

Suggested terminology: *concave lens, convex lens, converge, diverge.*

E12.6: The spectrum

An interesting consequence of refraction is the dispersion of white light into the colour spectrum of the rainbow. By allowing sunlight to pass through a prism, students will be able to observe the spectrum. If prisms are not available, a plane mirror can be placed on an angle in a shallow pan or bowl filled with water. Allow the sun's rays to shine into the water (they pass through a wedge of water and bounce off the mirror) and out of the water onto a screen. Questions such as the following may stimulate a variety of investigations:

- Is the order of the colours always the same? (In this last example, the spectrum is inverted by the mirror.)
- What happens if the original light beam is filtered through a piece of green, blue, or red glass?

Students might also want to investigate what happens when different proportions of the three colours (red, green, and blue-violet light) are mixed.

Suggested terminology: *prism, spectrum, dispersion, filter.*

UNIT E13: MAGNETISM AND ELECTRICITY

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
E13.1 Magnetic substances	1
E13.2 *Magnetic poles	1
E13.3 *Magnetic forces	1
E13.4 Magnetic fields	1
E13.5 Production of magnets	1
E13.6 The earth as a magnet	1
E13.7 *Electric charges	1
E13.8 *Electric attraction and repulsion	1
E13.9 *Electric current	1
E13.10 Electric cell	1
E13.11 *Electric circuit	1
E13.12 Series and parallel components	1
E13.13 *Electromagnets	1
Review and evaluation	2
	15

Preamble

This unit should be treated as an overview and not covered in depth, unless it is desired to expand this into more than one unit, in which case the extra time spent should be counted towards that allotted to a locally designed unit. Care should be taken to assess what the students already know about magnetism and electricity. For example, they may already be familiar with bar magnets and related terms and properties. Undesirable overlap must be avoided. If necessary, a brief, but interesting, review may be conducted.

This unit will involve students in a considerable amount of practical activity and investigation. Bar magnets, iron filings, small compasses, glass and Bakelite rods, wool and fur, cells and bulbs, switches, and wire are as important to this study as is any good textbook.

Magnetism and electricity are related forms of energy, since magnetism can be used to produce electric current and an electric current can be used to produce magnetism. At first, this unit focuses only on magnetism and then only on electrostatics, but through the use of a galvanometer to detect sources of electric current and through the electromagnet, the two forms of energy, magnetism and electricity, are brought together.

If the teacher wishes to have students measure magnetic forces in Topic E13.3, it would be well to refer back to Force and Energy (Unit E3), if not previously taught.

Careful examination should also be made of Unit S11, where some of the concepts recur; a satisfactory continuum between these corresponding elementary and secondary units should be established.

This unit should enable students to discover and learn the laws of magnetism and electric charges, and certain properties of magnetic fields and electric circuits. They should be able to make a magnet, a compass, and a simple galvanometer and to set up simple series and parallel circuits. They should also be able to demonstrate methods by which magnetic energy may be perceived, a method by which a solid can be proven to be a conductor or an insulator, and a method of detecting the flow of an electric current.

Theories involving magnetic molecules and charged electrons and protons are important in explaining observed phenomena.

E13.1: Magnetic substances

Using a bar magnet, students should be able to determine substances that can be attracted and those that cannot. They might try attracting a very fine stream of water from a tap (it won't be affected here, but it will later with electrical attraction). Perhaps students could be given the job of separating small nails from a bottle that contains a mixture of small nails and broken toothpicks. A loadstone, a horseshoe magnet, disc magnets, and other kinds of magnets (save electromagnets for later) should be examined.

Suggested terminology: *magnet, loadstone, bar magnet, horseshoe magnet.*

E13.2: Magnetic poles

A bar magnet should be placed on a flat surface and small nails dropped evenly over and around it. This can be done with a horseshoe magnet and perhaps with other kinds of magnets as well. The idea of poles should become apparent. Does the middle of a bar magnet have much magnetic strength?

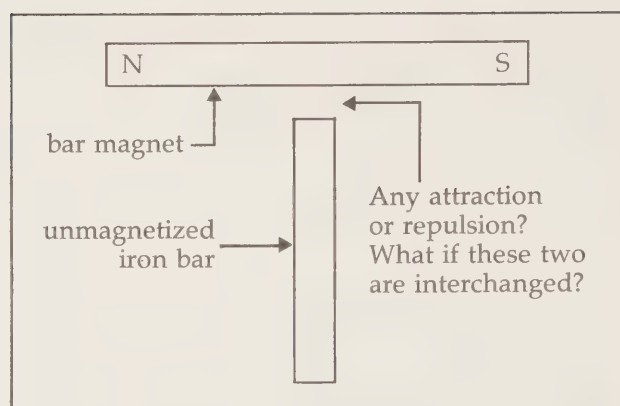
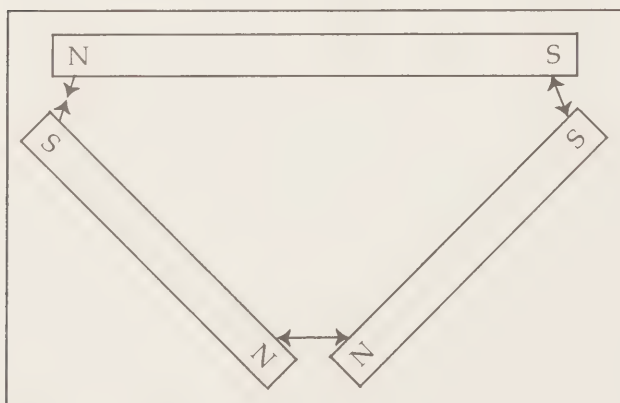
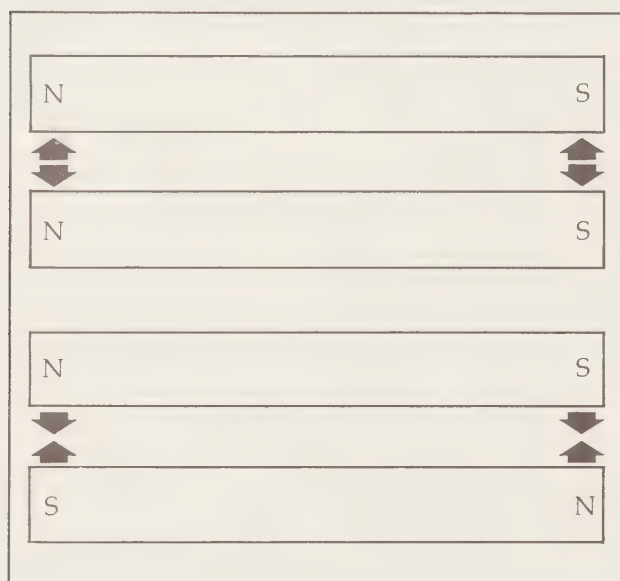
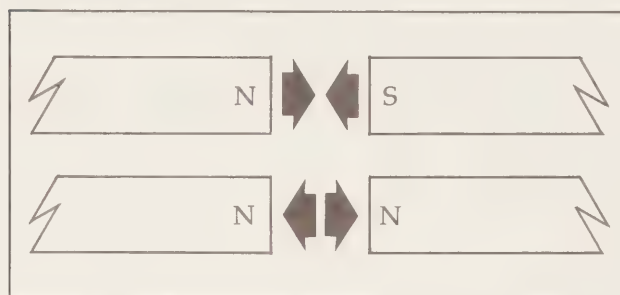
A bar magnet should then be suspended by string so that the magnet is free to turn in a horizontal plane. The terms "north pole" and "south pole" should be mentioned with reference to "north-seeking" and "south-seeking". See also Topic E13.6.

Suggested terminology: *north pole, south pole.*

E13.3: Magnetic forces

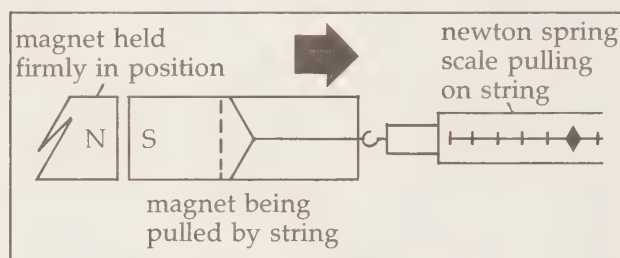
When the poles of two magnets have been established, like and unlike poles should be brought together, and students could then state the law of magnetic attraction and repulsion.

The students may be able to feel or visualize the forces exerted by magnets. By holding magnets in their hands in different positions, they can feel the directions in which magnets attract or repel one another. They might draw simple diagrams such as the following and use arrows to show magnetic forces.



Since students are expected to measure forces in newtons (see Unit E3: Force and Energy), it might be well to see if they can measure the force of attraction or repulsion between two magnets. They could compare the strengths of different magnets.

Suggested terminology: *like and unlike poles, magnetic attraction and repulsion.*



E13.4: Magnetic fields

Students can see the patterns formed when iron filings are sprinkled over paper that is placed over magnets in various positions. This could be done with some of the following: (a) unlike poles about 2 cm apart, (b) like poles about 2 cm apart, (c) a single magnet, (d) a horseshoe magnet, (e) parallel magnets attracting one another, (f) parallel magnets repelling one another.

Some students might become sufficiently acquainted with the idea of lines of force and their properties to give a theoretical explanation of magnetic effects. We say that the lines come out of an N-pole and enter an S-pole; they are continuous, passing through the magnet, out of the N-pole, and into the S-pole again. They tend to shorten (as though they were like stretched elastic bands). Parallel lines going in the same direction tend to repel or push each other apart, and lines of force tend to follow the path of least resistance. From simple drawings of magnetic fields, students can see how attraction and repulsion may be explained in terms of lines of force.

The three-dimensional aspect of a magnetic field is clearly illustrated by the following activity: Wrap a piece of paper neatly around one pole of a bar magnet and dip this in iron filings.

If time permits, students should place a strip of wood in the magnetic field near a magnet and observe the field by means of iron filings. This is then repeated with a piece of soft iron in place of the wood. (The wood and the soft iron should have the same dimensions.) Do lines of force pass through solid objects? What is the difference between the effect of wood and iron in a magnetic field?

Suggested terminology: *magnetic field, lines of force.*

E13.5: Production of magnets

A theoretical explanation of magnetism should be given to explain the arrangement of molecules in a bar of iron and what happens when it is magnetized. Students should make their own magnets using objects such as nails and needles, and then demagnetize them by heating or hammering. What care should be taken with commercial magnets?

Once the students have made their own magnets, they may be encouraged to apply them to further activities. They may wish to invent magnetic games or puzzles; no doubt those with vivid imaginations will create some interesting ones. For example:

- How can a magnet be made to roll uphill?
- Can three magnets be arranged to make a reasonably stable triangle (attraction at all three vertices)?
- Can a triangle of bar magnets have repulsion at all three vertices?
- Can a stable tetrahedron be made using six bar magnets?
- If two pieces of iron look identical, but only one is a magnet, how would you distinguish the magnet from the non-magnet without using other materials?

E13.6: The earth as a magnet

Is the earth a magnet? What evidence is there for or against the answer to this question? Students could come up with arguments or leave this issue as a supposition. If the earth is a magnet, why does the N-pole of a freely suspended magnet point to the N-pole of the earth when like poles repel one another?

If the earth is a magnet, it should have a magnetic field. If the field is strong enough, a steel needle or rod could be lined up with the field, tapped, and might thereby become a magnet. Students should try this, and if it works, there would be some tangible evidence to answer the question above. If it doesn't work, what can be concluded?

Students should know what a compass is composed of and how it works. They can design their own using a bowl of water, a magnetized sewing needle, and a cork.

There may be an opportunity to discuss related matters such as the difference between magnetic north and true north, angle of variation, and navigation by compass.

Suggested terminology: *north magnetic pole, compass, variation.*

E13.7: Electric charges

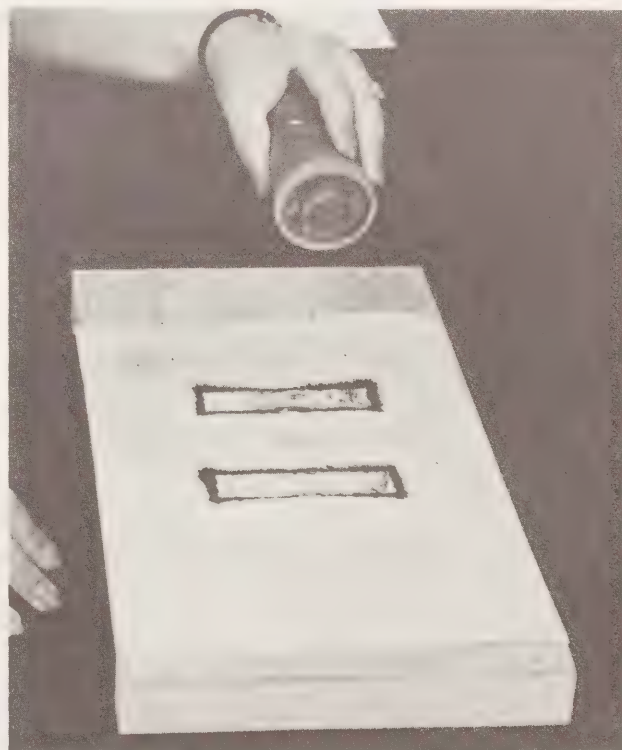
Students should give examples of electrostatic phenomena from their own experiences with electric charges: walking on a rug and touching metal; removing wool sweaters or nylon clothing; taking clothes out of a drier; combing hair on a dry, crisp, cold day; and so on.

To detect electric charges, students can make a simple electroscope with a pill bottle as follows: Pass a piece of insulated stiff wire through the bottle cap, leaving one end about 6 cm above the cap. The top end of the wire may be turned to form a small loop of bare wire. (A sharp end should be avoided, since electric charges leak off sharp points.) The lower end of the wire should be bent into the shape of a flat hook, from which is suspended a small piece of flexible foil. The two leaves of the foil should hang freely in the bottle.

Students can then rub together a number of substances — such as glass and paper, plastic and fur, comb and wool or hair, aluminum and cloth — and bring the first object in each pair near the top of the wire electroscope. What materials show evidence of an electric charge? Which show no effect?

Students might try attracting a very fine stream of water from a tap. This can be compared to its attraction to the bar magnet in Topic E13.1.

Suggested terminology: *electric charge, electroscope.*



E13.8: Electric attraction and repulsion

The following experiments can be conducted:

- Rub an inflated balloon against a piece of wool and then place the balloon so that it touches a wall. Why doesn't the balloon fall?
- Suspend two balloons by parallel strings so that the balloons are about 1 or 2 cm apart. Rub the balloons with wool and observe.



- Rub a glass rod with a piece of silk and suspend it horizontally so that it can turn readily. Bring another glass rod that has been rubbed with silk near it; then bring an ebonite rod that has been rubbed with fur near it.

Students should be able to conduct such experiments and learn that there are electric forces of attraction and repulsion. They should understand that the naming of positive and negative charges is quite arbitrary and they should learn the law of electric attraction and repulsion.

The explanation of negative and positive charges in terms of electrons and protons could be given in conjunction with a very simple model of the atom. The theoretical nature of this explanation should be emphasized.

Some applications of static electricity may also be noted and discussed.

Suggested terminology: *electric charges, positive and negative, electrons, protons.*

E13.9: Electric current

In order for students to investigate characteristics of an electric current – that is, the movement of charges from one point to another – they can carry out a very simple experiment or two. They can place a metal rod or thick wire across two plastic cups – the cups act as insulating stands. The pill-bottle electroscope (see Topic E13.7) is placed near one end of the rod. A piece of acetate charged with a cotton cloth is placed near the other end. (This may be repeated using a piece of vinyl plastic rubbed with wool.) The electroscope is observed for any response.

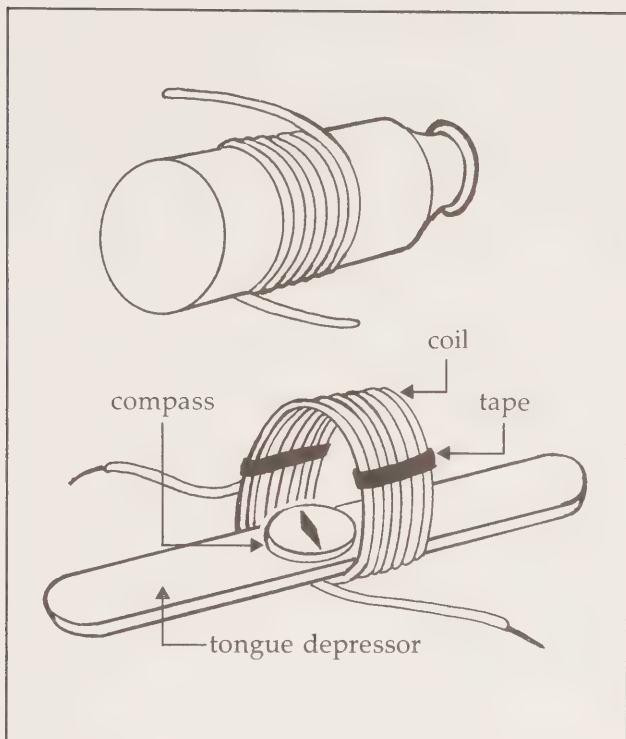
This experiment may be repeated using rods of different materials, for example, various metals, plastic, wood, glass, or a candle. Students should list those materials that allowed the charge to travel along them and those that did not. An examination of various appliances may be made to note which parts are electrical conductors and which are insulators.

Suggested terminology: *electric current, conductors and insulators.*

E13.10: Electric cell

Students can make one or two different kinds of cells in order to discover the essential components. One might be made of a lemon: A straightened steel paper clip is inserted into one side of a lemon and a piece of bare copper wire into the other. These two metals are then connected to some device that will detect an electric current. A simple galvanometer should do. It can be constructed as follows:

- Wrap about 7 m of #28 enamelled copper wire around the lower end of a small bottle (not too tightly and in one direction only).
- Carefully slip the coil away from the bottle and wrap it with small strips of tape to hold the turns together. Each end should be about 10 cm long and should be left free. (See the accompanying illustration.)
- Tape the coil to a tongue depressor and scrape off about 2 cm of the insulation from the free ends of the wire.
- Place a compass on the tongue depressor in the centre of the coil.
- Connect the ends of the coil to a flashlight cell very briefly and observe the compass. An electric current in the coil activates the compass (indirectly), particularly when the tongue depressor is in an east-west position at right angles to the normal direction of the compass. Students should know that this electric current detector is called a galvanometer.



The galvanometer can be connected to the “lemon” cell to see if the cell produces electricity.

A dry cell could be cut to show students its contents, which may be compared with the “electric lemon”. *Note: Because a cell often contains corrosive chemicals, it should be cut only by the teacher.*

Suggested terminology: *dry cell, galvanometer.*

E13.11: Electric circuit

Students could come to understand the meaning of a circuit by investigating different ways by which they can make a bulb light up by connecting it with a D dry cell. Besides the bulb and cell, they will need a 15 cm length of copper wire. They should be able to discover the essential condition needed to produce a continuous flow of current.

The idea of a circuit with various components (such as a source, a switch, conductors, and a resistor or load) is important.

As time permits, students may be able to investigate the following:

- Does it matter where the switch is located in the circuit?
- What is a short circuit and how is it prevented?
- What happens to the light bulb if two cells are used instead of one?
- What happens if one of the cells is placed “backwards” in the circuit?
- What happens if two bulbs are used instead of one?

Suggested terminology: *circuit, switch, resistor, conductor.*

E13.12: Series and parallel components

Because of time limitations, this study may have to be restricted to series and parallel connections of bulbs only. If time permits, series and parallel arrangements of cells could also be included. The students should discover that:

- in a series circuit, if one lamp burns out, the circuit is broken and all other lamps go out; and
- in a parallel circuit, if one lamp burns out, others may stay on.

They might deduce that:

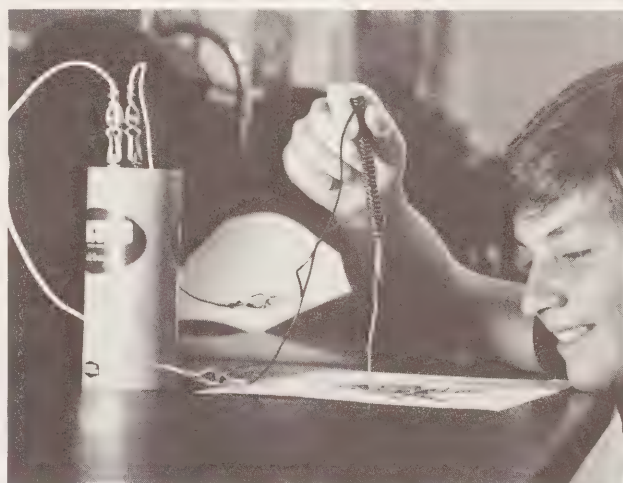
- in a series circuit, the total current flows through each bulb in succession; and
- in a parallel circuit, the total current splits, with only a part of the current flowing through each branch. Practical applications of series and parallel circuits may be discussed.

Suggested terminology: *series circuit, parallel circuit.*

E13.13: Electromagnets

Students can make an electromagnet and test it to determine when it is operative and when it isn’t. If the magnet is made by wrapping wire around large nails, students may compare the strength when only ten turns are used, when twenty are used, when thirty are used, and so on. They can test the strength by finding out how many small nails or tacks the magnet can pick up. They might investigate one or two practical applications of electromagnets.

Suggested terminology: *electromagnet, core, turns.*



UNIT E14: MINING RESOURCES

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
E14.1 *Why mine?	1
E14.2 How to find an ore body	3
E14.3 How to mine an ore body	3
E14.4 *Mineral processing	3
E14.5 *Smelting, converting, and refining	4
Review and evaluation	2
	16

Preamble

This unit looks at mining, one of Canada’s most important commercial natural resource industries. It is suggested that by using the project method and model-building approach, students can develop an understanding of the estimation of mining potential, the extraction of minerals, and the processing of metals. This unit could also be organized through questions and instruction to promote a study and analysis of the mineral industry of Ontario. Students should be encouraged to design their own questions around the topics presented.

Class discussion should encourage students to present their assessments of issues and situations with the use of as much factual material as possible. At the completion of this unit, students should have an understanding of some basic mining technology and a concern for soil, water, and air pollution.

Reference should be made to Rocks and Minerals (Unit E16) when considering the inclusion of this unit in a course of study.

Science teachers should also discuss this unit with geography teachers. Some topics, such as E14.3: How to mine an ore body, may be covered adequately in courses on geography and, therefore, would not be taught in a science course. Undue overlap must be avoided.

E14.1: Why mine?

We need metals, for industry and commerce, in pure form (such as gold, nickel, and copper) and in compounds (such as molybdenum oxide for some steel production). We mine minerals such as asbestos for insulation and silica for glass-making. Sand and gravel are mined for use in road construction and the manufacture of concrete. Students could expand on the uses of metals and minerals, especially on those that are mined locally.

Students could discuss the economic and political issues that dictate whether or not a mining operation is feasible. Such issues might include: the market possibilities (such as world demand), the right of an individual to stake a claim, existing government regulations concerning land purchase and mineral production, expected levels of expenditure for exploration and development (as for the Tar Sands), and possible trade-offs (for example, gravel pits versus hectares of asphalt).

“Why mine?” can, therefore, be answered in two parts:

- We need mined materials to support our way of life.
- We need mined minerals to export to balance our trade with other countries.

Other factors that determine the feasibility of a mining operation are:

- the position and accessibility of the site;
- the climate;
- the availability of supplies;
- the geology and mineralogy of the deposit;
- the mining methods required.

A brief historical approach to mining may be of interest. What minerals were used in the Stone Age, in Biblical times, in the Roman and Grecian empires, and in the Industrial Revolution?

Suggested terminology: *metal, compound, mineral.*

E14.2: How to find an ore body

Exploration techniques have improved remarkably from the days of the early prospectors. Students can gain a historical perspective on the nature of early prospecting from an examination of monographs on mining towns.

Today, geological, geophysical, and geochemical methods of exploration are necessary because of the following factors:

- Deposits are found as outcrops or in the earth’s subsurface.
- Most of the visible outcrops have already been located and exploited.
- Rocks and minerals have different physical and chemical properties, such as magnetic attraction, radioactivity, or the transmission of electric current (conductivity); such properties can be used to detect anomalies in the earth’s crust.

Students could also investigate methods of outcrop mapping, simple geochemical analysis of vegetation, and the use of diamond drill cores to determine the size of an ore body. An understanding of these will help students appreciate how science is applied through the technology used by the modern prospector-geologist.

Suggested terminology: *outcrop, geological, geophysical, geochemical, technology.*

E14.3: How to mine an ore body

There are at least four main factors to consider when planning to mine an area:

- staking – When does a prospector stake? What methods are used? What are some legal aspects of staking? (Examples: land claims by Native people, other citizens, organizations, and companies.)
- diamond drilling – What equipment is used? How are materials recovered? What are the ecological concerns connected with lubricant and sludge discharge and the location of a temporary camp for the drill crew?
- ore body characteristics — What is the depth, shape, grade, and size of the ore body? Are the rock and ore strong enough to hold themselves up? How may this rock and ore structure influence the choice of the mining method?
- suitable extraction methods – What ore characteristics determine the appropriate mining techniques (surface mining, placer, open-pit, or shaft)?

Methods are currently being perfected to recover mineral wealth from the ocean bottom. Students can be asked to describe one method of recovering such wealth. Why are such resources important? Will there be problems in recovering this mineral wealth? How can minerals be extracted from sea water?

Suggested terminology: *staking, diamond drilling, ore, extraction.*

E14.4: Mineral processing

The two main operations in mineral processing (milling) are:

- size reduction or liberation; and
- the separation of the valuable minerals into concentrates.

The following questions may be used to explore this topic:

- What are the four major metals found in sulphide ores? (iron, lead, zinc, copper)
- What precious metals are also found in these ores?
- What processes reduce the ore to particle size?
- How does a magnetic separator work?
- What is “gangue”? What are “tailings”?
- How can valuable minerals be concentrated by the process of froth flotation?

Students should not be expected to have a specific and detailed understanding of mineral processing. This topic could be used to exemplify a

concrete working example of the technology of science. In this regard, scale models of the machinery involved in these processes could be developed with the assistance of the industrial arts and technical teachers.

Suggested terminology: *gangue, tailings, froth flotation.*

E14.5: Smelting, converting, and refining

Smelting, converting, and refining are usually used to retrieve a metal from its concentrate. The following questions can be used to help students understand how copper, for example, can be extracted from copper-iron sulphide (chalcopyrite) ore.

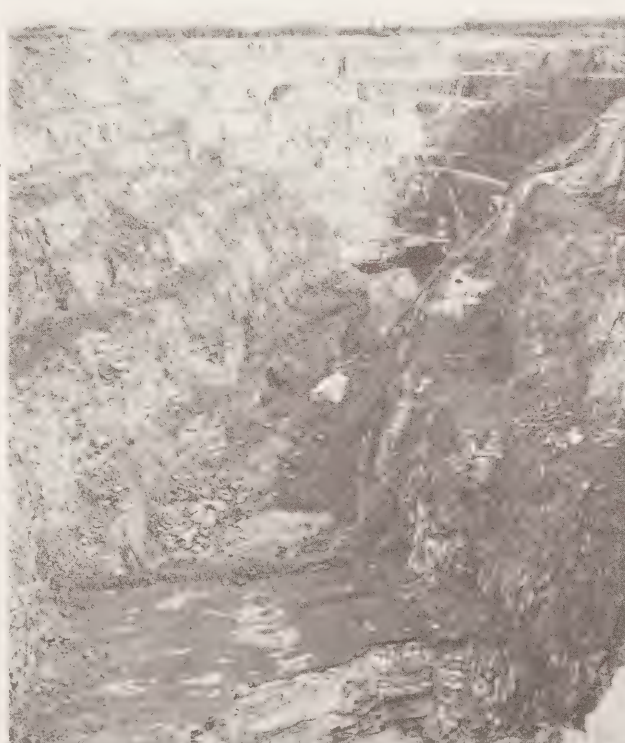
- What impurities are removed from copper in the copper smelter?
- How is sulphur oxidized to form sulphur dioxide?
- What is a flash smelting furnace?
- What happens to the sulphur dioxide gas produced in this process?
- How is “blister” copper produced in a converter?
- How has the “super stack” in Sudbury reduced sulphur dioxide damage to the immediate environment?
- How is pure copper produced by electrorefining?

This topic could be summarized by having students draw a simplified diagram of the processing of copper.

Students could hypothesize on the effects of a geographical redistribution of smelting processes, further processing, and the manufacturing of raw mineral resources. What would be the effect of such a redistribution on the Sudbury basin with respect to employment, social patterns, and the environment?

Suggested terminology: *smelting, converting, refining.*

Ontario Ministry of Land and Forests



UNIT E15: PLANTS

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
E15.1 Classification of plants	2
E15.2 *Plant structures	4
E15.3 *Flowers and fruits	2
E15.4 *Seeds	2
E15.5 Plant growth	3
E15.6 Plant projects	3
Review and evaluation	2
	18

Preamble

This unit provides students with a basic, practical understanding of the nature and importance of the plants in their immediate environment. Some appreciation for the need and basis for plant classification is useful to students.

It is probable that students have had some previous study of plants. It is therefore recommended that some effort be made to determine the extent of their current knowledge. A brief survey should suffice: the teacher must avoid boring the students by an unnecessary repetition of previous work. Perhaps new plants that have not been studied previously can be found and introduced for investigative purposes. The important thing is to discover where the students are in their studies and to proceed from there.

Interesting structural phenomena in plants should be observed and related to plant functions. Specific investigations should be provided to allow students to study flowers, fruits, seeds, and plant growth. It is important for students to study plants, and not merely to study *about* plants. Student-centred activities should be incorporated into this unit so that students can appreciate the structure and beauty of shrubs, trees, house plants, and even lichens. A basic concept of “plant adaptation” can be developed through student activities. Students should also appreciate the roles of the professional horticulturist and the home gardener.

E15.1: Classification of plants

Before beginning this topic, refer to Classification of Living Things (Unit E2).

Students could review the process of classification by looking at how the red Delicious apple tree is classified. Such classification includes the following terminology: kingdom, phylum, subphylum, class, order, family, genus, species, variety. However, the process, not the terminology, should be emphasized.

Students could collect specimens to illustrate the four major plant phyla – namely, thallophytes, bryophytes, pteridophytes, and spermatophytes. Similarities and differences between a conifer and deciduous tree could be noted. Students could examine the stems of herbaceous and woody plants and record their special characteristics.

Suggested terminology: *classification, kingdom, phylum, deciduous, coniferous.*

E15.2: Plant structures

Primary and secondary roots can be observed if radish seeds are germinated over several days. The root hairs can be observed by using a magnifying glass. What functions do root hairs have? The names and classification of root types should be reviewed and the external features of a tree twig identified. This is best done in late fall or early winter.

Students can observe a slice of a fairly large log and estimate the age of the tree. They can preserve the log slice with shellac or varnish for a school science museum. The cross-section of a herbaceous monocotyledon plant, such as a lily, tulip, or iris, can be observed and described. Leaves can be classified according to their size, shape, edges, and vein formation.

Suggested terminology: *root hair, monocotyledon.*

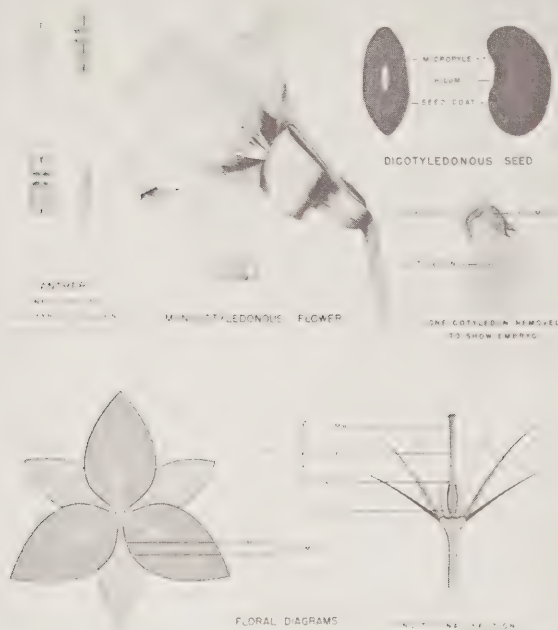
E15.3: Flowers and fruits

Students should become familiar with flower parts by examining a variety of flower heads such as the buttercup, toadflax, and morning glory. Identification of flower parts should include the corolla, calyx, stamen, pistil, anther, filament, stigma, style, and ovary. Audio-visual material can be used to advantage to illustrate pollination. Refer to Life Cycles (Unit E11).

The final stage of plant growth involves the formation of fruit. To a biologist, “fruit” means the ripened ovary from any flowering plant. Students might classify fruits. They could also discuss how cross-pollination and grafting are used to produce tastier, larger, and hardier fruits.

Suggested terminology: *corolla, calyx, stamen, pistil, anther, filament, style, ovary, pollination, fruit, grafting.*

FLOWER AND SEED STRUCTURE



E15.4: Seeds

The parts of a seed can be examined using lima beans and corn kernels. A lima bean is soaked in water overnight. The next day, the transparent seed coat is removed and examined. The two seed leaves are separated and the tiny embryo examined using a magnifying glass. Similarly, a soaked kernel of corn can be cut open and the corresponding structures located. The teacher can demonstrate the presence of food in seed leaves using Lugol's test for starch. The following questions may also be considered: How do seeds germinate? How could you show that germinating seeds give off carbon dioxide? How are seeds adapted for dispersal? Seeds can be classified according to their uses.

Suggested terminology: *seed, embryo, germination*.

E15.5: Plant growth

In this topic, students should explore the conditions necessary for plant growth and learn a little about the various ways in which plants may be grown. Students can grow plants from a root (sweet potato), a rhizome (iris), a tuber (potato), a bulb (narcissus), and a leaf (African violet). Planting bulbs for indoor winter bloom can be a rewarding activity for both student and teacher alike. Reference material should be studied thoroughly before bulbs and the method of forcing are chosen. Bulbs that are suitable for forcing include hyacinths, tulips, and daffodils.

Students should develop an understanding of the use of auxins. Auxins are a group of chemical substances that affect plant growth and reproduction. They can be used to produce seedless grapes and to promote growth in organs, to root plants, and even to keep apples on a tree.

Students should pursue some open-ended in-

vestigations as well as experimentation. Such investigations might include:

- Which part of an annual plant elongates as the plant grows tall?
- Do roots search for water?
- Why don't the buds on the sides of branches develop until the tip bud has been removed?
- What are some photoperiod effects that may be found in plants?
- What effect does an auxin have on fruit which prevents the fruit from falling?
- Observe and sketch the stages in the unfolding of a leaf from a bud.
- Describe and explain the response of roots to gravity.
- Explain how a tendril is able to twine around a string so rapidly.
- What part of the root produces new roots when stimulated by an auxin?

Suggested terminology: *rhizome, tuber, bulb, "forcing", auxin, photoperiod, tendril*.

E15.6: Plant projects

In this topic, suggestions are made to indicate how student-centred activities can be organized to look at a variety of practical applications of plant study. Such activities encourage students to be observant when outdoors and provide first-hand experiences in ecology. Students can examine their lawns and do a weed-distribution survey. A class graph could be developed to indicate the frequency of such weeds as dandelion, plantain, chickweed, and certain types of grasses. Methods of weed control should be tried and the results analysed. This activity should also help students to appreciate the achievement of weed-free homes and communities.

A tree-identification study is a useful activity to develop observation and recording skills in students. A tree checklist will indicate that at least twenty-five different kinds of trees may be found within a 2 km radius of many schools. Other identification projects could involve spring and autumn wild flowers, and fern, moss, and lichen varieties.

Woodland and desert terraria can be set up in the classroom using large aquaria and the right mixture of gravel, humus, and sand. Small ferns and mosses can be planted to replicate a woodland environment. The temperature should be kept between 18°C and 22°C. In making a desert community, students might plant cacti or yuccas, making sure to moisten the roots before planting and to water them lightly once a week. Students should keep data on terraria development and be able to account for any changes in the ecosystem.

Students can prepare and plant a perennial-flower border at school or at home to bloom from April until October. Such border plants could include the peony, delphinium, iris, Shasta daisy, sedum, and phlox. How does knowledge of the height and spread of such plants affect the design of a garden? Should annuals be used? If so, how and where?

Suggested terminology: *ecology, ecosystem, weed, perennial, annual*.

UNIT E16: ROCKS AND MINERALS

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
E16.1 *Differences between rocks and minerals	1
E16.2 *Rock classification	1
E16.3 *Rock formations	2
E16.4 Erosion and weathering	1
E16.5 *Energy fuels	1
E16.6 Fossil study	2
E16.7 Mineral-identification tests	3
E16.8 Crystal formation	2
E16.9 *Metallic minerals	1
E16.10 *Non-metallic minerals	1
E16.11 Gem minerals	1
Review and evaluation	2

18

Preamble

Human existence is conditioned by the structure and composition of the earth's crust and by the uses to which we put the natural resources contained therein. Students can become aware of these mineral resources through actual experiences, laboratory exercises, classroom projects, experiments, field trips, films, and slide presentations.

A student collection of rock and mineral samples could form an integral part of this unit. The teacher should not feel it necessary to be able to name every rock specimen brought in by a student. Such classification and naming is the job of a trained geologist. However, much can be learned about rocks and minerals without becoming involved with technical procedures and terminology.

As follow-up projects to this unit, students can explore the geological history of their local area, organize a rock and mineral club, or make jewellery with polished stones.

E16.1: Differences between rocks and minerals

Students frequently use the terms "rock" and "mineral" interchangeably. This topic should underline, with examples, the major differences between the two terms.

Suggested terminology: *rock, mineral.*

E16.2: Rock classification

Samples of the three main rock classes (igneous, sedimentary, and metamorphic) should be provided and classified before students set out to find their own specimens. Once students have obtained a few samples, they can investigate how such samples may have been formed. The classification of student samples is an important skill to be developed in this topic. A brief study of the earth's crust should be undertaken at this point in the unit. *Note: Geologists (Ministry of Natural Resources) have tended to replace the word "metamorphic" with "meta-volcanic", "meta-igneous", or "meta-sedimentary". This has reduced the confusion that "metamorphic" has often caused through the implication that it refers to different rocks instead of rocks that have been changed. The term "metamorphic" should still be explained because it will be found in many textbooks.*

Suggested terminology: *sedimentary, igneous, metamorphic.*

E16.3: Rock formations

A study and appreciation of igneous and metamorphic rock formations can be undertaken using films, filmstrips, and slides. A practical approach can be easily taken in the study of sedimentary-rock formation. Students could perforate the sides and bottom of a milk carton and partially fill it with a mixture of small quantities of sand, fine gravel, patching plaster, and poster paints. Some of the mixture can be added every day until the carton is full. The carton can then be torn away to expose the rock profile.

Students could also simulate natural sedimentation using a large glass jar, a long, tall cylinder, an aquarium, or a stream table. Natural dried soil or gravel should settle out into layers quite readily. Each day more can be added and a discussion can be held to determine why the layers occur, what might cause the soil to be dumped into lakes or oceans, and what the causes of thick and thin layers are.

A large sample of material taken from a riverside would be useful to show the similarities between real sedimentation and the classroom experimental sedimentation.

Suggested terminology: *rock profile, sedimentation.*



E16.4: Erosion and weathering

The concepts of erosion and weathering may be effectively understood if students are able to see first-hand how rocks behave under mechanical and chemical weathering. To simulate weathering, students can heat egg-sized rock specimens in a heavy frying pan and then drop the rocks into a pail of ice water. Some of them will break, especially those containing quartz. *Note: Caution should be exercised, as sandstone samples may explode upon heating. If classrooms do not have the necessary equipment to protect the eyes, then the teacher should carry out the demonstration.*

Students can also break old bricks into small pieces. Several of these small pieces can be put into a jar of water and the cap screwed on tightly. Students can then take turns shaking the jar vigorously while observing what is happening to the brick pieces. *Note: Bricks should be wrapped in a towel before breaking.*

Suggested terminology: *erosion, weathering.*

E16.5: Energy fuels

An appreciation of our dwindling energy resources should be emphasized in this topic. Students can investigate the origins of fossil fuels and their formation. Fossil fuels should be linked to fossils, so that students see that a chemical change is necessary to produce the fuels. They should realize the need for energy conservation and they can investigate the means by which several forms of energy can be conserved.

Suggested terminology: *fossil fuel, conservation.*

E16.6: Fossil study

Fossil fuels have been discussed in the previous topic, so students are now ready to investigate how fossils are formed. They can examine this phenomenon by covering a leaf with vaseline and placing it on a smooth surface. The following procedure is then carried out: A circular strip of cardboard or linoleum is placed around the leaf. Some plaster of Paris is poured over the leaf. This demonstration can be repeated using a greased clam or oyster shell. In localities that have stone quarries or rock outcrops, a field trip can be organized to collect fossils that can be later examined and classified.

Suggested terminology: *fossil, quarry, outcrop.*

E16.7: Mineral-identification tests

Students can bring mineral samples to the classroom. Such physical properties as hardness, streak, fracture and cleavage, colour and transparency, crystal form, smell, feel, and taste can be examined to give students experience in mineral-identification testing. *Note: Students should be allowed to taste, but only with the permission of the teacher.*

If one mineral scratches another, the scratch cannot be rubbed off. If the mark can be rubbed off, it indicates that the powder of the softer mineral has formed on the harder one and no scratch has been made. Moh's Hardness Scale can be introduced for use in testing for mineral hardness. On completion of this topic, students should be able to identify some minerals through simple identification tests.

Suggested terminology: *streak, fracture, cleavage, lustre.*

E16.8: Crystal formation

One mineral-identification test is the observation of crystal shapes. Students could develop an appreciation of crystal formation by making their own crystals. Crystals can be made using solutions of salt, sugar, alum, or copper sulphate. Sand can be examined under a microscope, possibly, to observe and identify grains of quartz crystals. *Note: The suggested crystal growths (except salt) do not occur naturally.*

Suggested terminology: *crystal, quartz.*



E16.9: Metallic minerals

Samples of metallic minerals containing copper, nickel, gold, silver, iron, and lead can be brought into the classroom. The origins and uses of these minerals can be discussed.

Suggested terminology: *metallic mineral.*

E16.10: Non-metallic minerals

Samples of non-metallic minerals, such as graphite, mica, sulphur, and talc, can be introduced into the classroom. Students can describe these samples and discuss their origins and uses. Students should be made aware of the fact that our natural resources are not renewable at our present rate of consumption and that we should endeavour to conserve them. Students can make a chart showing how metallic and non-metallic minerals have been used in the classroom. A "garbage detail" might also be assigned whereby students analyse one day's garbage in their homes. A discussion of our present "throw-away" society could follow. Refer also to Mining Resources (Unit E14) for wise, alternative uses of minerals.

Suggested terminology: *non-metallic mineral.*

E16.11: Gem minerals

A jeweller can be invited to the classroom to discuss gems and their desired qualities for making jewellery. A member of a local lapidary club or a gem dealer might also be invited to make a presentation. From such activities students can develop an appreciation of the aesthetic qualities of minerals and of their commercial value.

Suggested terminology: *gem, lapidary.*



UNIT E17: SIMPLE MACHINES

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
E17.1 *Concept of a machine	1
E17.2 *Our use of machines	1
E17.3 Simple and complex machines	1
E17.4 *Principle of work	2
E17.5 *Efficiency	1
E17.6 Mechanical advantage	1
E17.7 Concept of friction	1
E17.8 Experimental study of friction	2
E17.9 Experimental study of levers	1
E17.10 *Machines in our lives	1
Review and evaluation	2
	14

Preamble

Some topics in Force and Energy (Unit E3) are prerequisites for this unit. The study of simple machines is presented here as an optional unit for elementary schools. However, if a family of schools desires to continue this study at a greater depth in Grade 9 or 10, it is recommended that some of the optional topics suggested here may be placed in Machines (Unit S16). Such topics would be considered as optional in the secondary school program.

Students entering the Intermediate Division may have dealt with some types of machines in at least a preliminary manner. A teacher selecting this unit in Grade 7 or 8 should develop an approach that can stand on its own without excessively overlapping either with earlier treatments or with what may be planned for Grade 9 or 10. One such approach is to capitalize on the unique characteristics of students in Grades 7 and 8.

One of these characteristics is a burgeoning interest in social issues. Our increasing use of machines has not only produced immense benefits, but has also generated problems which the young adolescent should begin to relate to scientific concepts and data and to view within an emerging framework of personal values. Thus, the historical and social dimensions of the use of machines are given more attention than in traditional treatments.

Two other characteristics of young adolescents is their delight in forming hypotheses, and their markedly increasing ability to test hypotheses in a fairly rigorous fashion through controlled experiments. While this approach permeates the unit, it is particularly clear in the initial approach to machines in which students are invited to predict input and output relationships. These predictions are then tested experimentally, and the results are generalized in a "principle of work" that becomes the focus for the study of various types of simple machines.

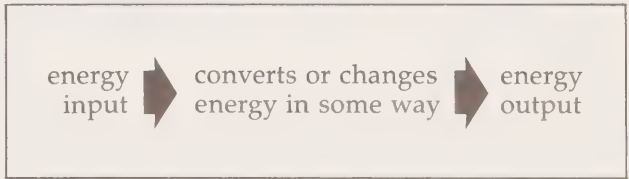
Science teachers should be concerned with the fact that the exact scientific meaning of the terms they use is quickly forgotten after students leave the science room. The possible antidote to this is to anchor such terms as "machine", "advantage", and "efficiency" to their everyday meanings. This should ensure their application in practical learning and their subsequent retention.

Before planning to teach this unit, the teacher should examine Measurement (Unit E5) and Force and Energy (Unit E3) so that undue overlapping may be avoided.

E17.1: Concept of a machine

Although students at this stage will be able to name examples of machines, few will have thought their way through to a consistent definition, or will think of the simple machines of this unit as examples of machines. Thus, a clarification of the meaning of "machine" will be useful and might proceed along the following lines:

- Have students give examples of machines they know.
- From these instances, develop a simple model for a machine.



- Test one machine against this definition: "Would a (pencil sharpener) be a machine?" This may then be repeated for a variety of machines named by the students and teacher – for example: a pulley, a can opener, a vacuum cleaner, a flashlight, a radio, a toaster, a steering wheel, a crowbar.

Suggested terminology: *machine, energy input, energy output.*

E17.2: Our use of machines

Students can compile a list of many types of machines that have been devised over the centuries. Individuals or groups of students may contribute parts of the class list. This inquiry should be oriented by the question: "What were people trying to accomplish when they invented this machine that they could not do without the machine?" The list should be arranged roughly in historical order so that the sequence of development may become apparent. From this study, the following generalizations should emerge: (a) Early civilizations invented and used most of the "simple machines", namely, the lever, inclined plane, wedge, wheel and axle, pulley, and screw. Such simple machines employed mechanical energy, which was mainly provided by human labour as an input. (b) In time, and particularly as slave labour became less available, people harnessed the energy of animals, such as horses, and natural phenomena, such as running water, as inputs to their machines. Later, they adapted chemical, electrical, thermal, and atomic energy for this purpose. (c) Gradually, the use of machines has broadened, from accomplishing tasks that would be impossible without machines, to doing things more efficiently and accurately, and to relieving people from tedious work. (d) Today, there may be some machines that could be classified as luxuries, particularly in view of the energy crisis.

A list of machines may take the following form:

Name of machine	Apparent purpose
club	to deliver a concentrated forceful blow at a point
wedge	to apply opposing splitting forces
catapult	to deliver a force at a distance
printing press	to allow multiple copying in a short time
steam engine	to provide a continuous mechanical output for vehicles (horses get tired)

Name of machine	Apparent purpose
car engine	to increase the speed and comfort of passenger travel
mail sorter	to increase the speed and accuracy of sorting letters
electric toothbrush	to increase toothbrushing efficiency and to promote the massaging of gums
electric can opener	to make it easier and faster for humans to open a tin can
electric lather dispenser	to provide another push-button convenience to save human energy

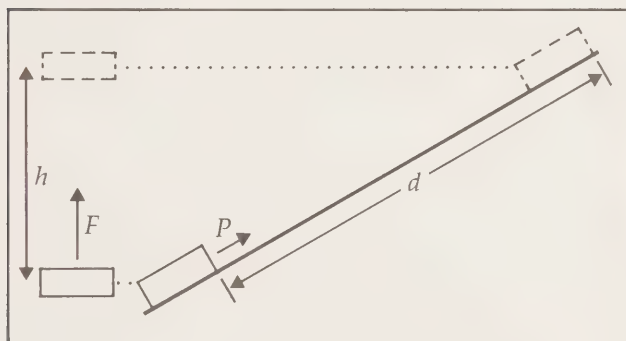
Suggested terminology: *simple machines, lever, pulley, wheel and axle, inclined plane, wedge, screw.*

E17.3: Simple and complex machines

Since this unit focuses on simple machines, it is wise to have students see the connection between these and the more complex machines in which they may be interested. One way in which modern machines are complex is in their use of various kinds of energy. Complex machines generally involve combinations of a number of simple machines working together in a co-ordinated way. Students may be given an opportunity to examine the action of a complex machine and to classify its parts in terms of simple machines. They may recognize connecting rods as levers, gears as examples of the wheel and axle, and a cam as an inclined plane. If feasible, arrangements may be made for students to examine machines outside the science room, such as a sewing machine, a typewriter, a car engine, farm equipment, and machine tools. Old or used equipment may be available. Parts should be visible and manipulated to permit the study of cause-and-effect relationships. With technically inclined students, vocabulary, including terms such as "engines" and "prime movers", may be expanded to enrich this topic.

E17.4: Principle of work

Students might be confronted with a problem such as the following: a 5 kg load must be raised to a platform through a height of 30 cm. The outcome of this task is to exert a force (F) of 50 N through a height (h) of 0.30 m. The work output = $Fh = 50 \text{ N} \times 0.30 \text{ m} = 15 \text{ J}$. Now the same task is done using a machine – an inclined plane, for example (a wooden board will do). This machine accomplishes the same output as before – namely 15 J of output – but an input agency, such as a student, pulls with a force P (measured with a newton spring scale) parallel to the ramp and through a distance d along this oblique path. The work input is Pd . Before the students make any measurements, the following questions may be posed: Is d greater or less than h ? Is P greater or less than F ? Is Pd greater or less than Fh ? Is the input work greater or less than the output? What do the students predict? The students then verify their predictions by measuring, calculating, and tabulating their results.



Students may predict a variety of results, depending on their knowledge of the principle of conservation of energy. They will find that $Pd > Fh$, that is, work input > work output. For example, suppose $P = 30 \text{ N}$ only, but $d = 60 \text{ cm}$, then the work input = $Pd = 30 \text{ N} \times 0.60 \text{ m} = 18 \text{ J}$. Hence, the input of 18 J = the output of 15 J + energy loss of 3 J. The teacher can discuss what might be named the “principle of work”, that is, work input = useful work output + wasted work or energy, and can illustrate this principle with examples.

Suggested terminology: *principle of work, joule.*

E17.5: Efficiency

Students may be asked to state how they would describe the efficiency of a machine such as an inclined plane or even of a person. They may suggest that “efficient” describes one who wastes little effort in performing a task, and “efficiency” may be the ratio of the work a person accomplishes to the effort put into the job. This suggests a similar means for expressing the efficiency of a simple machine, the ratio of work output to work input, shown either as a decimal fraction or per cent. Students could then determine the efficiency of the inclined plane and perhaps discuss how this might be improved.

Suggested terminology: *efficiency.*

E17.6: Mechanical advantage

If a machine’s work output is less than the energy input, why use it? This may be asked of students. The key questions are first, “What’s the advantage?”, and then, “Can we calculate the advantage?” Thus, the discussion can lead to defining the mechanical advantage of a machine as the ratio of the output force to the input force or the “load” to the “effort”. In the above example,

$$\text{M.A.} = F/P = \frac{50 \text{ N}}{30 \text{ N}} \doteq 1.7.$$

If time permits, students should be given the chance to use a few simple machines, such as a system of pulleys, a wheel and axle, an inclined plane set at different angles, and have the experience of determining the work input and output, the efficiency, and the mechanical advantage.

Suggested terminology: *mechanical advantage.*



E17.7: Concept of friction

Friction was earlier identified with the loss of work in a simple machine. This means that friction involves force – called the force of friction. Students should be encouraged to speculate on the physical basis of friction – irregularities on surfaces interlocking or rubbing against one another. This analysis, coupled with experience, will suggest ways to reduce friction: (a) polishing (removing the bumps from) one or more of the surfaces involved, for example, sanding the surfaces of telescoping rods; (b) smoothing out the bumps in the surfaces by coating them with another substance, for example, waxing skis; (c) inserting a fluid between the two surfaces, for example, oiling a hinge; (d) substituting rolling friction for sliding friction, for example, putting wooden dowels under a heavy object to move it along the floor.

Some advantages of friction might be discussed. For example, friction retards motion, but it also provides traction.

Suggested terminology: *force of friction, lubrication.*

E17.8: Experimental study of friction

Students are encouraged to form their own hypotheses and test these by means of simple experiments. The following are some examples of possible hypotheses:

- The force of sliding friction is *greater than/is less than/is the same as* the force of starting friction.
- Sliding friction *increases/decreases/remains unchanged* as the speed between two sliding surfaces increases.
- The force of friction between a block of wood and a platform *increases/decreases/remains unchanged* as the area of surface contact increases.
- Rolling friction is *less than/greater than/equal to* sliding friction.

Suggested terminology: *starting friction, sliding friction, rolling friction.*

E17.9: Experimental study of levers

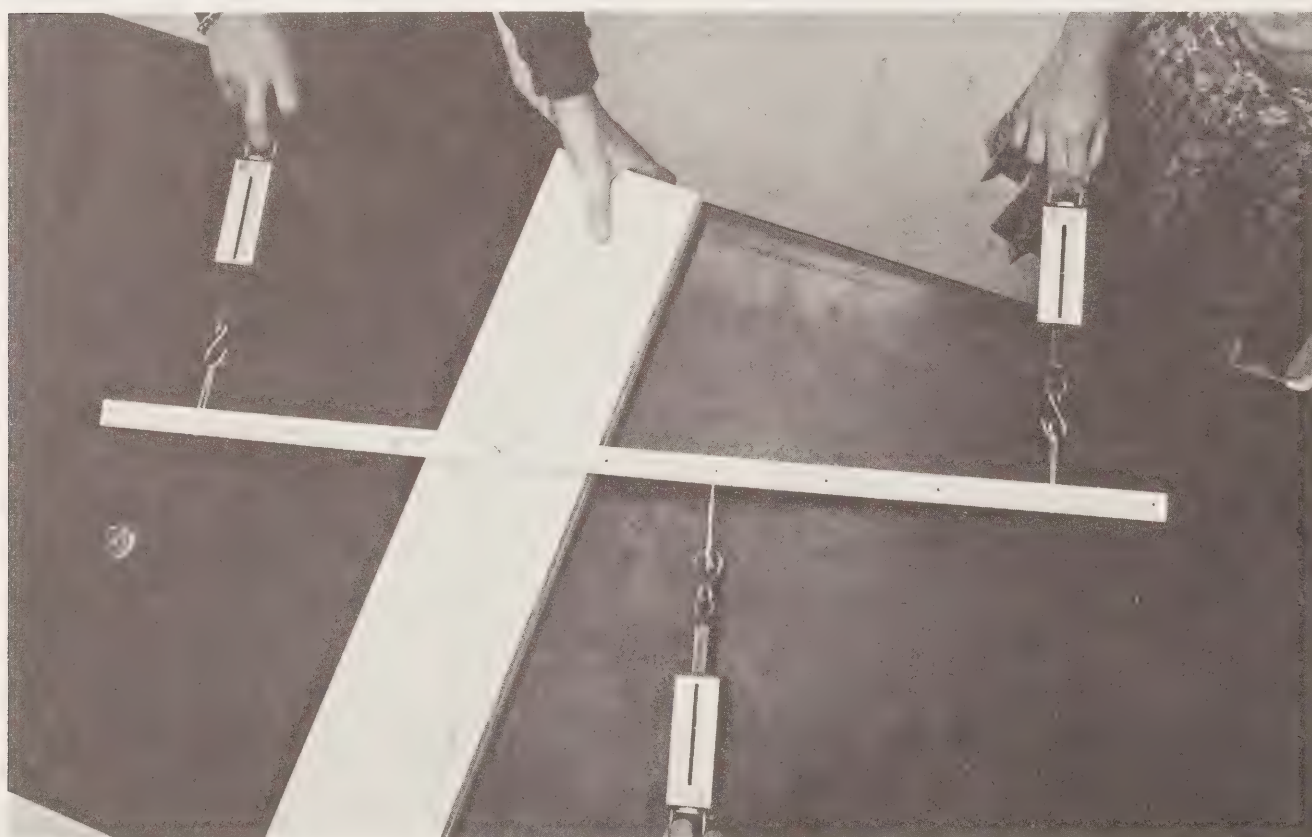
Forces are measured in newtons, not grams or kilograms. It would, therefore, be misleading to support a metre stick on a fulcrum and to suspend masses from the beam, even though they do exert forces on the beam. If this is done, the students should determine the force, in newtons, exerted by each mass. One possibility is to allow the metre stick, which acts as a lever, to pivot on a horizontal pegboard with the metre stick and the applied forces lying and acting in the horizontal plane. All forces should act at right angles to the beam. One

advantage of this is that the force of gravity acting on the beam may be disregarded. Another is the chance for the students to feel the tug of the forces as they pull on the newton spring scales that are applied to the metre stick.

On their own, students might “discover” the law of the lever, namely, $\text{effort force} \times \text{effort arm} = \text{load force} \times \text{load arm}$. The left and right side of this equation should not be confused with work input and output. Examples of the applications of levers in everyday life should make this topic realistic.

E17.10: Machines in our lives

At this stage, students are not likely to have reflected deeply on the significance of machines in the life of the individual. This unit may well conclude with such a study, possibly a joint effort among science, history, and geography teachers. Topics for consideration may focus on the disadvantages of machines (in contrast with the rest of the unit, which implies that they are advantageous). The following may be suitable topics: (a) danger to one's safety through malfunction or misuse; (b) pollution of the environment, particularly by machines that use large amounts of chemical energy; (c) loss of exercise when machines replace basic forms of exercise such as walking, digging, and lifting; (d) technological displacement of humans by machines; (e) reduction in the craftsmanship of individual items or artifacts; (f) the danger or fear that complex machines will take over more and more human functions, including the ability to make decisions.



UNIT E18: SOLUTIONS

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
E18.1 *Characteristics of a solution	2
E18.2 *Saturated and unsaturated solutions	2
E18.3 *Supersaturated solutions	1
E18.4 *Testing for degree of saturation	1
E18.5 Crystals	2
E18.6 *Rate of solution	4
E18.7 Exothermic and endothermic reactions	1
E18.8 *Water, the "universal solvent"	2
Review and evaluation	2
	17

Preamble

In their daily lives, students encounter a wide variety of solutions. For instance, the air is a solution of gases; stainless steel is a solution of metals; and pop is a solution of a solid and a gas in a liquid. Through the study of this unit, students should gain an understanding of the concept "solution".

This unit focuses on the characteristics of solutions, some solution terminology, the nature of the dissolving process, and, finally, the role of water as the so-called universal solvent. The unit should be primarily experimental in nature, allowing students to increase their skills in accurate observation, measurement, graphing, hypothesizing, and model-building. The topics in this unit may lead to the further study of temperature, water chemistry, environmental chemistry, and aquatic environments in other science courses.

Further information regarding investigations of solutions may be found in Solutions (Unit S19). This unit may be blended to some extent with Water (Unit E19).

E18.1: Characteristics of a solution

A solution is a mixture of substances in which one substance, the solute, dissolves in another substance, the solvent. In operational terms, a solution is a homogeneous mixture. Students should have the opportunity to prepare and investigate several solutions. They should be able to identify the solute and the solvent in each case. The following characteristics of a water (aqueous) solution should be readily observed by the student:

- The solution is transparent (whether coloured or not).
- The solute does not settle on standing.
- The solute cannot be filtered from the solution.
- The solute cannot be seen with the aid of a magnifying glass.

Suggested terminology: *solute, solvent, solution, filtering*.

E18.2: Saturated and unsaturated solutions

A saturated solution contains all the solute it can dissolve at a given temperature. An unsaturated solution contains less solute than it can dissolve at a given temperature. Students should be able to relate these terms to actual experiences, such as dissolving various amounts of sugar in water, as in coffee or tea. Students should have the opportunity to investigate the crystal formation that occurs when the solvent is allowed to evaporate from a saturated solution.

Suggested terminology: *saturated, unsaturated, evaporation, crystal*.

E18.3: Supersaturated solutions

A supersaturated solution contains more solute than it should be able to dissolve at a given temperature. Some substances, such as sodium thiosulphate, are capable of producing this unstable condition. Teachers should review the use of a heat source if one is used in this topic. *Note: Teachers should refer to Appendix B: Laboratory Safety.* The development of psychomotor skills can be stressed as students work with test tubes, heat sources, and seed crystals.

Suggested terminology: *supersaturated*.

E18.4: Testing for degree of saturation

If a seed crystal is added to a solution, careful observation will reveal whether the solution is unsaturated, saturated, or supersaturated. Students should be able to test for the degree of saturation in a solution.

Suggested terminology: *seed crystal*.

E18.5: Crystals

Crystals can form as a solvent evaporates, when a supersaturated solution is "seeded", or when a solution cools and the solvent solidifies. Students could seed a supersaturated solution of sodium thiosulphate (hypo) to initiate crystallization. Using magnifiers, students can observe several of the crystals formed and can sketch simple diagrams of the crystal shapes. A data table could be used to organize other crystal observations. If time permits, students could observe and produce other crystals such as salt, sugar, bluestone, alum, Rochelle salt, and calcite.

Suggested terminology: *crystal, crystallization.*

E18.6: Rate of solution

Students should be able to identify the following five factors as influencing the rate of solution (dissolving): (a) heating the mixture, (b) stirring the mixture, (c) the state of subdivision of the solute, (d) the nature of the solute, (e) the nature of the solvent. Students should be able to give an example investigation to illustrate each factor. For example, an investigation of the first three factors could be undertaken by dissolving sugar in water. To illustrate the fourth factor, the rate of solution of sugar in water may be contrasted with the rate of solution of table salt in water. To illustrate the fifth factor, the rate of solution of sugar in water may be contrasted with the rate of solution of sugar in methanol (ditto fluid).

Suggested terminology: *rate of solution, factor.*



E18.7: Exothermic and endothermic reactions

Teachers may be able to capitalize on observations that students have made during the earlier investigations of the characteristics of solutions. A number of investigations should be made to illustrate the fact that some solutions give off energy as dissolving takes place. For example, when sulphuric acid or sodium hydroxide is dissolved in water, heat is released and the resulting solution becomes warm. This process can be described as being exothermic. However, other solutions absorb energy as dissolving takes place. For example, when such solutes as ammonium chloride or sodium acetate are dissolved in water, heat is absorbed and the solution cools. This process would be described as endothermic. *Note: Extreme care must be exercised when using acids or bases. See Appendix B.*

Suggested terminology: *exothermic, endothermic.*

E18.8: Water, the universal solvent

This topic allows the student to make a connection between the study of solutions and the environment. Students should know that the following properties make water a useful and convenient solvent:

- Water is a readily available liquid.
- Water is readily moved from one place to another.
- Water is non-flammable.
- Water is non-toxic.
- Water dissolves a large number of substances.

Many examples could be listed of the use of water as a solvent.

Although water is available, it would be well to stress that this natural resource is not limitless. Further, it takes vast amounts of energy to supply water for all our needs. Students should become concerned because industry, municipalities, and individuals find it so easy to eliminate waste by flushing it through a sewage system with copious quantities of water. Students should be encouraged to suggest alternatives to such waste disposal techniques, perhaps with reference to *their own classroom practices.*

UNIT E19: WATER

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
E19.1 *The water cycle	2
E19.2 *The physics of water	3
E19.3 The chemistry of water	2
E19.4 *Water treatment	1
E19.5 *Water and living things	3
E19.6 Water as a land-changer	2
E19.7 Water in weather	2
E19.8 *Conservation of water	2
Review and evaluation	2
19	

Preamble

All life is intimately associated with water. No other chemical compound is so abundant on the surface of the earth. What people see when they describe weather is really water or the absence of it. In this unit, students can look at some of the physical properties of water and develop skills of prediction and explanation. The chemical nature of water can be tested to uncover reasons for the abundance of organisms in lakes and streams. The pervasive uses and effects of water should be observed, measured, and analysed in student investigations. Activities are recommended that can broaden and deepen the student’s appreciation and wiser use of our most important natural resource.

Since certain topics in some geography courses may overlap with this unit, science teachers are urged to discuss their intended treatment of topics with the school’s geography teachers. Undue overlap must be avoided. For example, Topic E19.6 may be adequately covered in either geography or science. However, if this topic becomes a part of both courses, teachers should ensure that it is taught from different perspectives that complement one another.

The treatment of this unit will also depend on the selection or rejection of a number of other optional units such as Solutions (Unit E18) and Weather (Unit E20). In all cases, overlap of content or approach should be carefully considered in order to avoid undue repetition.

E19.1: The water cycle

All water on earth is constantly evaporating to form water vapour. (See also Unit E20: Weather.) From what sources does this evaporation take place? How does this water vapour condense back into water again? Students should understand that the processes of evaporation and condensation go on in a continuous manner. This is called the “water cycle”. Very little ground water is thought to go down below 2 km of surface rock; however, the total amount and value of underground water are most significant. How is ground water released into the water cycle? A diagram could indicate how the following processes are involved in the water cycle: precipitation, sublimation, evaporation, transpiration, and infiltration. How would the absence of living things modify this cycle?

The moderating effect on climate of large bodies of water should be explained.

Suggested terminology: *water cycle, evaporation, condensation, transpiration, infiltration.*

E19.2: The physics of water

Students could observe some drops of water on waxed paper. Are drops of other liquids the same size and shape? Do different surfaces affect the size and shape of water drops? Which magnifies newsprint more, a clear drop of water or a soapy drop of water? Will a water drop remain well formed on top of an oil pool? If a drop of oil, a drop of water, and a drop of soapy water are rolled down a slanted piece of glass, which wins the race? Can water in a beaker support the mass of a dry, double-edged razor blade?

These simple investigations and others can help the student to observe, question, predict, design and perform experiments, and collect and analyse data related to properties of water. There is no need at this level to introduce such scientific expressions as viscosity, adhesion, and surface tension, unless desirable. If not done previously in another unit, other experiments or demonstrations can be performed to show the following:

- the condensation temperature of a room;
- the lowest temperature of an ice-and-salt mixture;
- that evaporation is a cooling process;
- that water contracts most (has its maximum density) at 4°C.

The changes of state of water should be examined experimentally. Students can look for everyday evidences of these changes of state and relate these to gain or loss of heat. Although water is by far the most familiar of all liquids, it has, nevertheless, many unusual properties. To summarize this topic, students could list such properties.

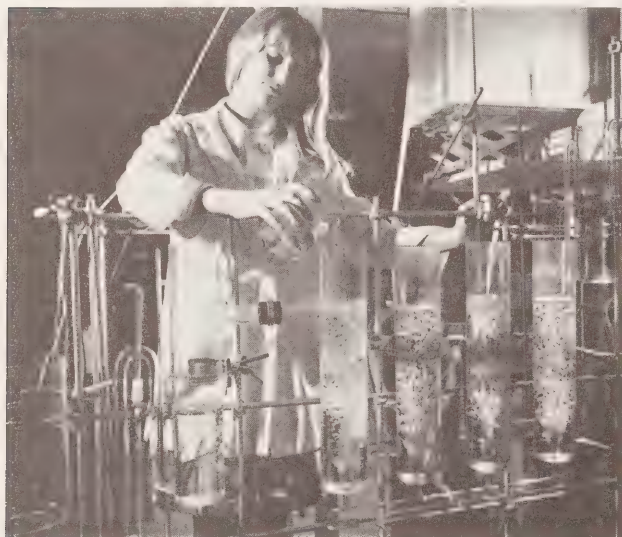
Suggested terminology: *changes of state.*

E19.3: The chemistry of water

Water is sometimes called the universal solvent. Explain this statement. Refer to Solutions (Unit E18) for information on solubility. Students should understand that water is a pure substance and also a compound composed of the elements oxygen and hydrogen. Students could be exposed to simple molecular structures of water, oxygen, and hydrogen. Similarly, word equations showing the decomposition of water and the burning of hydrogen in air can be introduced to consolidate the concepts of "element" and "compound".

Commercial water-testing kits are available to test for oxygen, carbon dioxide, ammonia, calcium, magnesium, phosphate, and chloride ions in water. In a general way, reference may be made to pH as an indication of the chloride ions in water, or of the acidity or alkalinity of water. Distilled water has a pH of 7, acidic water less than 7, and alkaline water more than 7. Water with a pH less than 7 provides little surface growth and is less productive than water with a higher pH level. A chemical profile of a boggy, decay-rich, acidic lake with a pH of 6.5 could be oxygen – 8 p.p.m. (parts per million), carbon dioxide – 10 p.p.m. Students can chemically test water to answer questions related to the presence or absence of fresh-water organisms. Why are there no fish in a lake? Why does a lake have good oxygen content and also many crustaceans that need very little oxygen?

Suggested terminology: *solvent, pure substance, compound, element, decomposition, distilled water.*



E19.4: Water treatment

Filtration plays an essential role in the purification of water supplies. Students could describe the use of alum, filter beds, and settling basins in this process. Solutes cannot always be separated from water by filtration. However, separation may be accomplished by boiling the solution and cooling the vapour so formed until it condenses. Water, then, can be further purified by distillation. Students should understand how water, and perhaps other liquids like petroleum, can be distilled. An appreciation of the uses of distilled water is important. A visit to a local filtration plant can consolidate the concepts developed in this topic. The dangers of drinking unknown water may be stressed.

Suggested terminology: *filtration, solute, solvent, distillation.*

E19.5: Water and living things

It is useful for students to learn about their own water intake and about the water requirements of animals and plants. An understanding of the water composition of living tissues lays a good foundation for later study of cell metabolism. Students can determine the mass of fresh and dried quarters of apple or potato and, hence, derive the percentage of water that was in each when it was fresh. They can also determine the amount or percentage of water in other common foods.

From collected data on the amount of food and water consumed in a day, a rough approximation of how much water students take in during a single day can be made. From such records a student's water requirement can be compared with that of a dog or a cat, allowing for the differences in size of the animal (compare masses).

To get a rough idea of how much water transpires from the leaves of a plant, a layer of plastic can be placed over the soil in which it is growing to seal it off from the air above. The plant is weighed, set aside, and weighed again after several days. The loss in mass gives some indication of the amount of water that transpired during the course of the activity.

Students can perform other investigations in this topic to develop observation and measurement skills. The role of water in the germination of seeds and in the growth of plants, and the ways in which animals get their water, are some other activities that could be incorporated into this topic. *Caution: Do not deprive animals of water when testing for water requirements.*

Suggested terminology: *tissue, metabolism.*

E19.6: Water as a land-changer

Water in all its forms has tremendous erosive power. Liquid water dissolves rocks and minerals and washes away loose particles of soil; waves erode shorelines; ice grinds against rocks or can split them apart. Students can simulate erosion by shaking a small piece of soft brick in a container half full of water. They can investigate the factors that might contribute to land erosion by rainfall, namely, slope, type of soil, protection from wind, loosening or trampling of soil and ground cover by animals, as well as the duration, extent, and intensity of the rainfall. Where is erosion likely to be the greatest? The least? What steps can be taken to reduce the likelihood of erosion? Samples of muddy streams can be collected and the sediment in them measured. By filtration, students can determine the amount of sediment contained in a 5 L sample of water. At what rate in cubic metres per minute was the stream flowing? How much sediment in kilograms or tonnes was the stream carrying per day? Students should realize that water is not only an erosive agent, but also has building capabilities, producing, for example, beaches, moraines, and eskers.

Suggested terminology: *erosion, sediment.*

E19.7: Water in weather

Without water vapour in the air, much of what we call weather would not occur. The addition of water vapour to the air makes it lighter, as it displaces some of the heavier gases. Students can measure rainfall by using a funnel to collect the rain incident on a large area and to direct it into a can. Students can relate the amount of rainfall to different cloud types and wind directions. The water content of snow can be determined. How much water is left when 20 cm of heavy, wet snow are melted? When 20 cm of powdery snow are melted? From samples taken during a few weeks of winter, what seems to be the average water content of snow?



E19.8: Conservation of water

This topic could be used to acquaint students with the dangers of water misuse, waste, and pollution that the world faces today. Students can investigate their home use of water in various ways. The number of litres of water used by a person in taking a bath can be calculated using a calibrated pail to graduate the inside of the tub. Students can measure how much water is used in flushing a toilet. This can be simply done by shutting off the supply pipe, flushing the toilet, and refilling the tank a litre at a time using a calibrated pail. Students can also estimate and then measure how many litres of water are used to water a lawn or wash a car. The amount of water used annually for various purposes may be determined to impress students with the need to consider conservation measures every day.

The water demands of a local industry can be studied to answer the questions: Does the industrial worker or the person at home use more water? Do some industries use more water than others? It may be possible to find out or to suggest ways in which the use of water by these industries can be decreased.

UNIT E20: WEATHER

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
E20.1 Nature of the atmosphere	1
E20.2 *Physics of air	2
E20.3 *Water in the atmosphere	1
E20.4 *Characteristics of precipitation	2
E20.5 Measuring and recording atmospheric conditions	4
E20.6 Clouds	2
E20.7 Weather forecasting	2
E20.8 Lightning	1
E20.9 Air pollution and weather	1
Review and evaluation	2
	18

Preamble

An understanding of the nature of weather phenomena and their impact on human life is important to students at this stage in their development. In studying weather, students can apply laboratory procedures in investigating the physical properties of air. A variety of methods is encouraged for the recording of weather data obtained by students. They should develop competence in the use of such weather-measuring instruments as barometers, hygrometers, anemometers, and rain gauges. Measurements should be recorded only in SI units, wherever possible. This unit should develop an appreciation for scientific estimation of atmospheric conditions and for the uncertainty of these conditions. An appreciation for the aesthetic value of such natural phenomena as snow patterns or a towering cumulonimbus thunderstorm should be fostered through student discussion and investigation.

There may be some treatment of weather or meteorology in geography courses. Therefore, it is essential that geography and science teachers discuss the problem of overlap. Care must be taken to avoid unnecessary duplication of content in both disciplines. If similar topics are taught in geography and science, they should be treated from different but complimentary perspectives.

This unit may be closely associated with such units as Solutions (Unit E18) and Water (Unit E19).

E20.1: Nature of the atmosphere

Students should consider the structure of the earth's envelope and be able to describe the three layers: the troposphere, stratosphere, and ionosphere. The nature of the atmosphere with respect to its temperature, pressure, and gaseous composition could be discussed, and the role of water vapour in the atmosphere may be emphasized. Audio-visual materials are useful in showing the structure of the atmosphere and in relating this structure to mountain heights, jet-aircraft zones, and cloud formation.

Suggested terminology: *atmosphere, troposphere, stratosphere, ionosphere.*

E20.2: Physics of air

In this topic, it is suggested that students perform simple investigations designed to illustrate some important characteristics of air. Such investigations would allow students to discover that:

- Air occupies space.
- Air occupies more space when it is warmed and less space when it is cooled.
- Air has mass.
- Air exerts pressure.
- Air can be compressed.
- Air becomes warmer as it is compressed and cooler as it expands.

Students could possibly perform these activities in rotating laboratory groups of two or three students each. Each group might demonstrate its activity to the class and develop questions in order to bring out the important observations, inferences, and explanations.

Suggested terminology: *mass, pressure.*

E20.3: Water in the atmosphere

This topic allows students to discover that water vapour enters the atmosphere by evaporation from bodies of water, from soil, and from plants, and that it is produced in some chemical reactions. Students can devise simple activities to answer the following questions:

- Does a wet sponge change in mass when left suspended in the air?
- Is there any mass lost when a flower pot full of moist soil is left for 24 h?
- Do plants lose water through their leaves?
- Is water produced when a candle burns?
- Why do moisture and frost form on the inside of windows and doors in severely cold weather?

Suggested terminology: *water vapour, evaporation, condensation, frost, transpiration.*

E20.4: Characteristics of precipitation

To a meteorologist, precipitation refers to the process by which water vapour condenses and falls to the ground. In order for condensation to occur there must be sufficient moisture, a cooling effect, and particles for the moisture to condense on. Students can consider the following questions: What are three major types of clouds? What is the dew point of the atmosphere? How can a “cloud” be produced in a milk bottle? How can “rain” be produced using a hot plate, a beaker, and a cup? How have pollutants and volcanic eruptions affected rainfall? Students can study frost formation using dry ice or a salt-ice mixture. *Caution: Dry ice has a temperature of -80°C and may cause severe damage if touched directly. Therefore, gloves or tongs should be used in the handling of dry ice.*

Suggested terminology: *meteorologist, precipitation, dry ice.*

E20.5: Measuring and recording atmospheric conditions

This topic involves students in direct visual observations and instrumental recordings of the atmosphere. The initial measuring experiences of students should be visual. Other senses, such as hearing and feeling, may be used to supplement seeing. Students should have opportunities to estimate wind speed, identify cloud types, and measure amounts of precipitation and visibility. Some class time may be used to debate whether the sensitivity of people's joints (in diseases like rheumatism) is related to weather changes. It is expected that most

of the weather data that students will use will be collected through their field-trip experiences, using weather-kit instruments. Students should develop a variety of methods of recording data, such as charts, tables, and graphs. Creativity could be fostered by allowing students to construct weather instruments as projects. A visit to a weather station is strongly suggested.

Students should develop competence in SI measurement when measuring wind speed, atmospheric pressure, temperature, visibility, amounts of precipitation, and distance. For example, the speed range for light winds is up to 20 km/h; those over 115 km/h are hurricane-force winds. The normal range of atmospheric pressure measured on barometers is from 98.0 to 103.0 kPa (kilopascals). A warm front could be located 200 km west of a city. Temperatures are recorded in degrees Celsius and amounts of snowfall and rainfall in centimetres and millimetres respectively. Visibility is measured in kilometres and metres.

Students could develop expertise and competence in the use of such weather instruments as the maximum and minimum thermometer, the aneroid barometer, the anemometer, and the wet and dry bulb hygrometer. They could consider the following questions: Where is the best location for a hygrometer? What is the purpose of a partial vacuum in an aneroid barometer? Why do professionals mount thermometers horizontally rather than vertically? Students could give some interpretation of the sources of error and loss of accuracy in instruments that measure wind speed and direction.

Suggested terminology: *atmospheric pressure, barometer, anemometer, hygrometer, maximum and minimum thermometer, humidity, kilopascal.*



E20.6: Clouds

A cloud to a meteorologist is a collection of minute water or ice particles which are sufficiently numerous to be seen. Students can describe how clouds may be classified according to height and appearance. The teacher should indicate why condensation nuclei serve as building blocks for cloud formation. The process of “cloud seeding” could be discussed. How are fogs produced? Students can distinguish between orographic and cumuliform clouds (frontal and convectional). This topic could encourage creativity in the students through their writing poetry about the weather and cloud formation.

Suggested terminology: *orographic* and *cumuliform clouds*.

E20.7: Weather forecasting

Weather can be defined as “the state of the air at any given time”. The simplest indicators of weather are clouds, wind direction, and visibility. What are other weather signs? Students should be encouraged to make such observations on their way to and from school in order to consolidate their thinking skills. By observing weather conditions over a period of time, students can predict local weather. Using their observations, they can infer an event: for example, cirrus clouds indicate the formation of a front. Students can also interpret and explain their observations of events. By testing an interpretation about why something happens as it does, they can develop the skill of hypothesizing. Throughout this topic, students will develop an appreciation for the scientific estimation of atmospheric conditions and the difficulties involved in predicting. Students should realize that predictions are tentative and subject to revision. They could describe how weather satellites provide important information to the forecaster. This topic may be enriched by discussing some myths and folklore related to weather.

Suggested terminology: *weather*, *front*, *cirrus cloud*, *weather satellite*.

E20.8: Lightning

Lightning is a tremendous spark between areas where positive and negative electric charges become concentrated. Many investigators believe that the process of charge separation is associated with differences in the size of water and ice particles and vertical air currents in clouds. The teacher can discuss how an electric field is established in a cloud. Students should understand the process by which a large electric potential between a cloud and the ground is built up so that lightning occurs. They should understand the stages of lightning. What is the amount of electric energy produced in an active thunderstorm? What causes the thunder that accompanies lightning? This topic should acquaint students with the basic safety rules connected with lightning.

Suggested terminology: *electric charge*, *electric potential*.

E20.9: Air pollution and weather

This topic should help students appreciate the seriousness of the pollution of the atmosphere and should suggest positive steps to remedy this situation. What are the main kinds of air pollution? How long has pollution been with us? What are the effects of air pollution? How does weather affect air pollution? What is an air inversion? What can be done about air pollution?

Suggested terminology: *pollution*, *air inversion*.



UNIT S1: CELLS AND THEIR PROCESSES

In this core unit, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic in the unit.

Topics	Number of Periods
S1.1 *Cell discovery, microscope	2
S1.2 Cell theory	1
S1.3 *Cell structure	3
S1.4 *Cell physiology	6
S1.5 *Mitosis (reproduction)	2
S1.6 Cell differentiation	2
S1.7 *Cell organization	1
S1.8 *Diffusion and osmosis	3
Review and evaluation	2

22

Preamble

About 1665, Robert Hooke coined the word “cell” to describe little structures he saw in slices of cork. Subsequently, he published his findings in a book called *Micrographia*. Further investigations by other naturalists and biologists established the cell as the basic unit of biological activity. In this unit, students should be made aware of some of the historical developments leading to modern cell theory. Cellular structures are studied to explore their functions, and processes in the same way that photosynthesis and respiration are investigated to understand energy reactions in cells.

A generalized study of mitosis should enable students to comprehend the phenomenon whereby every cell in an organism is produced from the division of parent cells. A brief treatment of the differentiation and organization of cells is also included in order to present, in a general way, the diversity of cell structure and function. Investigations performed in this unit should allow students to become proficient in the use and care of the compound light microscope. Many investigations require them to observe microscopic structures, to record their findings by diagram, and to classify experimental data. A general cell model should become apparent from such investigations and class discussions.

S1.1: Cell discovery, microscope

The microscope allows students to enlarge their view of the world. For example, when an ordinary microscope is used, bacteria in the range of 2 to 5 μm (micrometres) can be seen. The work of Leeuwenhoek and his contemporaries should be discussed. How has the meaning of the word “cell” changed since Hooke’s time? In tracing some of the history and development of the microscope, students should have some knowledge of the evolution of the modern microscope and its use as a scientific instrument. If time permits, they should be encouraged to read about this historical development.

Students should be familiar with the basic parts of a compound microscope and be able to use them in an appropriate manner. They can label a diagram of a microscope and identify its various parts.

Instruction should be given in the appropriate use of the diaphragm and mirror and in the focusing of the low- and high-power objectives. This should lead to an understanding of the three-dimensional nature of living cells. The distortions caused by imperfect illumination and lack of contrast should be noted by the students.



The diameter of the field of view can be determined in micrometres and nanometres (nm) by using a small, plastic millimetre ruler on the stage under low power. Using high power, students could measure an insect's leg, the width of a hair, and, possibly, the diameter of a red blood cell.

The electron microscope was invented in the 1930s by two Canadians, A. Brebus and J. Hillier, and can reach magnifications as high as 600 000 diameters, thus revealing particles as small as $0.003\text{ }\mu\text{m}$ (3 nm). If appropriate, the functions and uses of the electron and optical microscopes can be compared. Students should develop an appreciation of the microscope as an important scientific tool. In summary, this topic emphasizes the need for, and the development of, student skills in the proper use of the compound light microscope.

Suggested terminology: *compound light microscope, diaphragm, objective, ocular, stage, focusing wheels, electron microscope.*

S1.2: Cell theory

In 1839, Matthias Jakob Schleiden and Theodor Schwann published some ideas based on their interpretation and observation of cells. When accepted by other investigators, these ideas became known as "cell theory". The three main ideas of cell theory are as follows:

- The cell is the unit of structure of living organisms.
- The cell is the unit of function of living organisms.
- All cells come from previously existing cells.

The discussion of cell theory can be summarized by asking students to explain why these cell ideas were referred to as a theory and not a law.

Students should be given some experience in describing various cells in terms of their shape and size. They can discuss how microscopic technology has added to our historical knowledge of cells and, more recently, to cellular biochemistry. At the end of this unit, students should have time to synthesize the main ideas in cell theory in terms of any cell model that has been generated in the study of cell structure in the next topic.

Suggested terminology: *cell, theory, law, organism.*

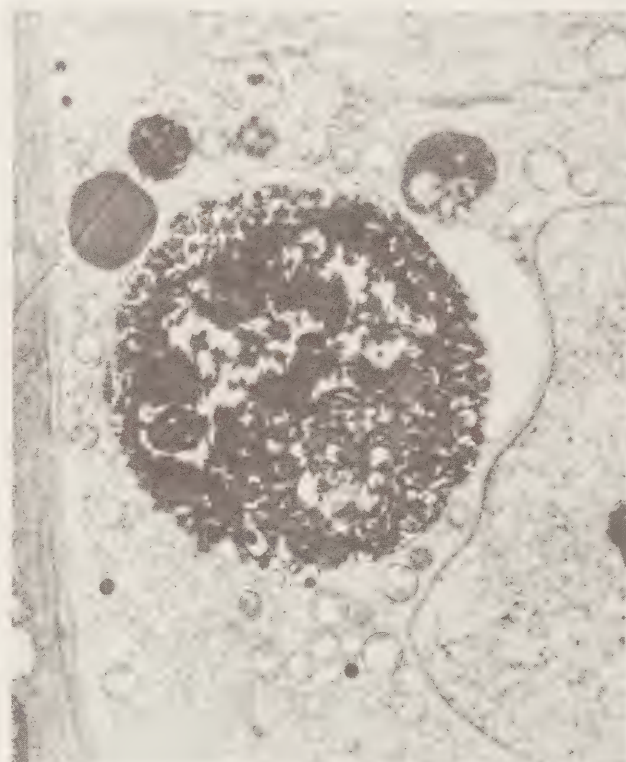
S1.3: Cell structure

Students could examine, under low, medium, and high power, the inner lining of an onion skin after staining it with iodine solution. A labelled diagram should be made of one of these cells. Students can also examine cells scraped from the inner surface of the cheek. How do these cells differ in their arrangement from those of the onion skin?

An elodea leaf can be examined under wet mount, and a diagram can be drawn to show what structures the cells contain and how the cells are arranged. Protozoa, such as amoebas and paramecia, can be examined and their visible cell

components identified. After these or similar investigations, students should be able to describe the structure of major cell components. The functions may be studied from reading and further experimental activities. If there is sufficient time, students can consolidate their concept of the cell by constructing a three-dimensional model from cardboard, styrofoam, or some other handy material. The development of an appreciation of the wide diversity of cell types and cellular components should be an important consideration in the teaching of this unit.

Suggested terminology: *cell wall, membrane, nucleus, vacuole, cytoplasm, chloroplast, organelle, mitochondria.*



S1.4: Cell physiology

Students should investigate the process of photosynthesis and respiration in green plants by experimentally studying the following:

- the presence of starch and sugar in green leaves;
- the need for light energy;
- the presence of chlorophyll in leaves;
- the role and production of carbon dioxide and oxygen.

These investigations allow students to demonstrate and account for the various reactants and products in photosynthesis and respiration. It is suggested that students could be involved in the designing of procedures to test hypotheses. It is also important that the concept of the controlled experiment be used, where possible, in student investigations.

The word equations for photosynthesis and respiration should be known, as well as the interrelationships between these two reactions. It is advised that students be given some background in simple organic chemistry before these investigations are attempted. However, teachers are cautioned to keep any discussion of the ADP-ATP (adenosine diphosphate, adenosine triphosphate) energy mechanism to a brief statement.

Suggested terminology: *chlorophyll, photosynthesis, respiration, carbon dioxide, oxygen.*

S1.5: Mitosis (reproduction)

Mitosis involves the duplication of the chromatin of a cell and its equal division between two daughter cells. Mitosis investigations can be performed using onion roots as a plant source. Alternatively, students can observe the principal mitotic events through a microscopic-slide study. Students should understand that the terms "mitosis" and "cell division" are not synonymous. Stages of mitosis are not to be emphasized, although students should be able to describe the principal events that occur during the process of mitosis.

Suggested terminology: *mitosis, cell division, chromosome, chromatin.*

S1.6: Cell differentiation

The evidence for cell differentiation should be discussed. The fact that all somatic cells have the same genetic material but may carry on different functions in any multicellular organism should be accounted for. How do unicellular and multicellular organisms differ with respect to aging? Students could comment on the hypothesis that aging is dependent upon some "chemical clock" running down. Why does much of the money available for cancer research go into studies of cell differentiation? From this topic, students should develop some appreciation for the complexity of modern cellular, biochemical research.

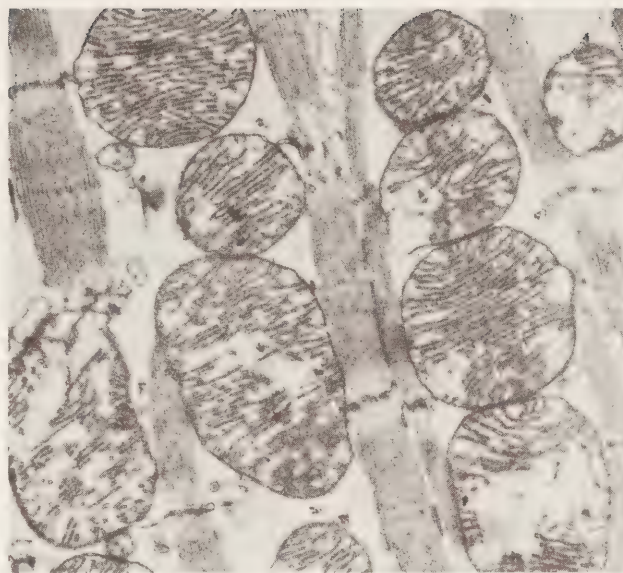
Suggested terminology: *differentiation, unicellular, multicellular.*

S1.7: Cell organization

A group of cells having similar structures and functional characteristics is called a tissue. Further organization produces organs. Students should be able to describe, with examples, cell organization in terms of tissues, organs, and organ systems in selected plants and animals.

Prepared slides of cross sections of plant and animal tissues could be studied to observe the shape and distribution of different cells. Students could suggest explanations for certain arrangements of cells seen in leaf tissues.

Suggested terminology: *tissue, organ, organ system.*



S1.8: Diffusion and osmosis

Before any osmosis investigations are performed in this topic, it is suggested that the process of diffusion be related to the kinetic molecular theory through an introductory discussion. Caution is urged here to fit the level of difficulty of the explanation to suit the abilities of the students. Students should investigate diffusion through a membrane, using such materials as cellulose tubing, starch, glucose, and iodine solutions. Students should have a good understanding of the chemical nature of solutions used in such osmosis reactions. Note that the diffusion of such gases as oxygen and carbon dioxide through a membrane is not osmosis. Plant cells can also be used to demonstrate osmosis and cell turgor.

This topic should give students a good understanding of the principles involved in diffusion and osmosis. This understanding should include the classification of membranes into permeable, impermeable, and differentially permeable categories.

Suggested terminology: *diffusion, osmosis, turgor, membrane, root hair, permeable, impermeable, differentially permeable.*

UNIT S2: CHEMICAL CHANGE

In this core unit, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic in the unit.

Topics	Number of Periods
S2.1 *Chemical change	3
S2.2 *Word equations	0.5
S2.3 Chemical equations	0.5
S2.4 Conservation of mass	1
S2.5 Balancing chemical equations	1
S2.6 Conservation of mass and the open system	1
S2.7 Qualitative tests	4
S2.8 *Studies of chemical change	8
Review and evaluation	2
	21

Preamble

This unit is intended to give students a basic knowledge of the “macro-evidence” that suggests that new material has been formed in a chemical reaction. It is expected that students will be given ample opportunity to develop laboratory skills. Before students are allowed to begin an experimental study of this unit, it is suggested that the rules of laboratory safety be reviewed.

The study of chemical equations involving symbols is included to support the development of the concept of conservation of mass. However, teachers should decide to what depth this topic and other optional topics are to be pursued.

In Topic S2.7, students are introduced to the concept of qualitative testing. These tests give students further examples of chemical reactions and introduce the concept of chemical change in the identification of substances.

An opportunity is provided in the concluding topic for students to apply their newly acquired knowledge and skills in an integrated project. It is necessary for the teacher to select *only one* of the modes suggested. The teacher may wish to refer to Properties of Matter (Unit E6) in order to prepare students for the study of this unit. This unit would normally form a sequel to Structure of Matter (Unit S8); however, the formal arrangement is left to the teacher. This unit can provide a background for the study of any optional unit that has a chemical basis.

S2.1: Chemical change

This topic is concerned with the existence of bulk or “macro-evidence” that a new material has been formed during a chemical change. The teacher must keep in mind that some students may have difficulty in making connections between questions, observations, and terminology, as illustrated here:

Question	Observation	Terminology
What evidence is there that a new substance is being formed?	Students can observe a change in physical and chemical properties.	“Chemical change” is given an operational definition.

It should be of benefit to link the question directly to the observation and then to derive the chemical terminology. Students should be given the opportunity to investigate a number of chemical changes so that they may become familiar with evidence that suggests that a new material has been formed. They should separate any physical changes that they note from the chemical changes observed.

Students should be exposed to an operational definition of chemical change which can be subject to redefinition at a later time. Chemical changes are often accompanied by one or more of the following: a change in colour, the production of heat, the production of light, a change in crystalline form, the formation of a gas, the formation of a precipitate. Some examples of chemical change include:

- the electrolysis of water (liquid) to produce oxygen (gas) and hydrogen (gas);
- the heating of sodium hydrogen carbonate (white solid) to produce carbon dioxide (gas);
- the burning of coal (black solid) to produce energy in the form of heat and light, carbon dioxide (colourless gas) and water vapour (colourless gas), and an ash differing in crystalline form from the original black solid;
- the reaction of a solution of barium nitrate (clear solution) and a solution of sodium sulphate (clear solution) to produce barium sulphate (white solid) and sodium sulphate (clear solution).

Teachers may also wish to introduce examples of non-chemical changes. One might consider the various changes of state of water or the crushing of pieces of bluestone into a powder.

Suggested terminology: *chemical change, precipitate, crystal shape.*

S2.2: Word equations

Chemical changes can be described by word and chemical equations. Students can write word equations representing simple reactions, such as:

- hydrogen reacts with oxygen to produce water and energy:
hydrogen (g) + oxygen (g) → water (l) + heat
- sodium hydroxide reacts with hydrochloric acid to produce sodium chloride and water
sodium hydroxide (aq) + hydrochloric acid (aq) → sodium chloride (aq) + water (l).

It is suggested that such word equations be written as representations of reactions that the student has investigated or that the teachers has demonstrated.

Suggested terminology: *word equations, aqueous.*

S2.3: Chemical equations

Students should understand that chemists, where possible, use symbols to represent chemical substances and equations to represent chemical reactions. The teacher may decide at this point to illustrate several simple chemical equations that do not involve balancing. Students should understand that the chemical equation presents a great deal of information in symbolic form. Students can be asked, for example, what information is presented in the following chemical equation:



Suggested terminology: *chemical symbols, chemical equations.*

S2.4: Conservation of mass

Certain reactions can lead students to question the quantitative as well as the qualitative relationships involved in chemical reactions. Students should understand that under certain conditions mass can be shown to be conserved in a chemical reaction.

The reaction of lead (II) nitrate solution and sodium iodide solution in a closed system is a typical experiment to illustrate the concept of the conservation of mass. Careful consideration of other reactions will produce further examples. These investigations will also help students to develop further their skills in the use of the balance. A brief review of the use of the balance may be necessary before beginning this topic. (See Topic S6.7.)

Suggested terminology: *conservation of mass, closed system.*

S2.5: Balancing chemical equations

Although it is not suggested that students attempt to develop a mathematical relationship between the conservation of atoms and the conservation of mass, they might be expected to know that in an ordinary chemical reaction atoms are neither created nor destroyed. Students could be asked to balance simple chemical equations, such as:



Suggested terminology: *balanced equation.*

S2.6: Conservation of mass and the open system

Some students could be asked to explain an investigation that does not appear to support the law of conservation of mass. For example: a burning candle placed on a watch glass on a balance pan decreases in mass and appears to refute the law of conservation of mass. *Caution: Whenever students use a source of open flame, they must be reminded of the basic safety procedures involved.*

Suggested terminology: *open system.*

S2.7: Qualitative tests

Qualitative tests are used in the laboratory to identify different chemical substances. Students should be able to associate a particular test with the presence of a particular substance.

Some possible tests that students can perform include the following:

- oxygen: glowing splint test;
- carbon dioxide: limewater test;
- water: anhydrous copper sulphate or cobalt chloride test;
- iron ion: potassium ferrocyanide test;
- calcium: oxalate test or flame test;
- sulphate: barium nitrate test.

During these testing procedures, the psychomotor skills appropriate to the chemical laboratory can be emphasized. Such skills could include the use of a Bunsen burner, collecting a gas, using a dropper, testing a gas with a splint, pouring liquids and solids, decanting, and filtering. Students can be reminded that such chemical tests are also examples of chemical changes.

Students must realize that a negative test is as important as a positive one and that careful reporting of results is necessary in either case. The teacher should ensure that students are given the opportunity to evaluate both positive and negative tests. This topic lends itself to an evaluation of laboratory procedures and techniques.

Suggested terminology: *qualitative analysis, test, decant, filter.*

S2.8: Studies of chemical change

This topic is designed to allow the teacher some flexibility in proceeding with the study of chemical change. Three approaches are suggested — inorganic, physical, and analytical. The teacher may choose any one of these approaches to continue the study of chemical change. The approach chosen should reflect the background and abilities of the students. *Note: Safety precautions must be observed throughout this topic. (See Appendix B.)*

Inorganic mode:

This approach to the study of chemical change could involve considering three aspects of a substance: its production, its identification, and its representative reactions. A suitable substance for study is oxygen. When methods of production are investigated, teachers should note that *safety must be a prime consideration if the students are to use potassium chlorate as the source of oxygen*. An alternative source of oxygen is hydrogen peroxide in reaction with manganese dioxide or potassium permanganate. Certain representative reactions might be conducted using the oxygen produced. For instance, reactions of oxygen with carbon, iron, and magnesium to produce the respective oxides could be studied. Each of these oxides could then be dissolved in water and the resulting solutions tested for an acid or a base.

Suggested terminology: *production, glowing splint test, oxide, acid, base.*

Physical mode:

In this approach to the study of chemical change, the factors affecting the rate of a chemical reaction would be studied. The rate of a chemical change might be considered from the standpoints of the effect of heat, concentration, surface area, and the presence of a catalyst.

To study the effect of heat, Alka-Seltzer tablets can be dissolved in water of varying temperatures. Class results of the rate of dissolution could lead to the production of a time-temperature graph. The effect of concentration can be studied by observing the reaction of a known mass of magnesium ribbon with varying concentrations of hydrochloric acid. *Note: Safety precautions must be observed when handling acids.* The effect of surface area can be established using marble chips and dilute hydrochloric acid. To show the effect of a catalyst, hydrogen peroxide can be decomposed in the presence and absence of manganese dioxide.

Suggested terminology: *concentration, surface area, catalyst, rate.*

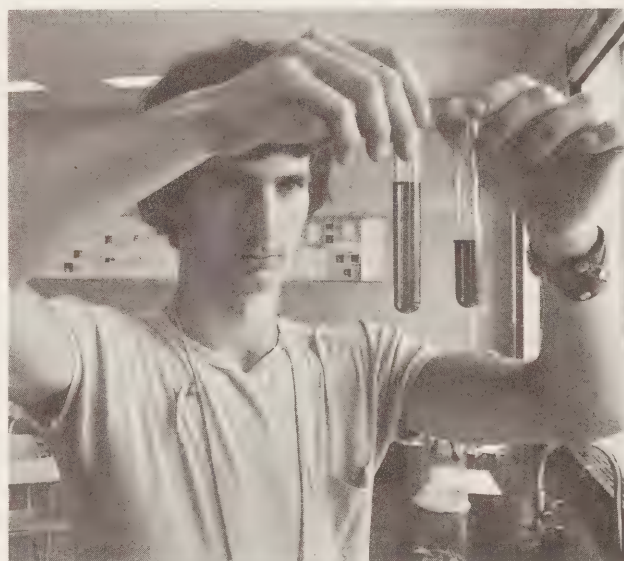
Analytical mode:

A qualitative analysis of pure substances can be used to study chemical change. Any substance chosen should be complex enough to challenge the students, but not so complex that it defies analysis by them. In choosing this mode, the teacher must carefully consider the ability of the students in the class. The concept of chemical analysis is difficult for many students, and they may require a great deal of assistance in evaluating the results of their investigations.

Bluestone crystals could be analysed qualitatively using the following procedure:

- Analysis for copper: if an iron nail is placed in a solution of copper (II) sulphate (made by dissolving bluestone crystals in water), the blue colour of the solution will disappear overnight, leaving a red deposit.
- Analysis for sulphate: if barium nitrate solution is added to a solution of powdered bluestone, a white precipitate of barium sulphate will be produced.
- Analysis for water: if bluestone crystals are heated, they will turn white, indicating that a chemical change has taken place. If the vapour produced is allowed to strike a cold surface, a liquid condenses. This liquid can be shown to be water if it is tested with cobalt chloride test paper. How could students show that the water produced was originally present in the bluestone crystals?

Suggested terminology: *analysis, test, precipitate, condensation.*



UNIT S3: FUNCTIONING ANIMALS

In this core unit, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic in the unit.

Topics	Number of Periods
S3.1 Metabolism	1
S3.2 *Breathing systems	4
S3.3 *Gas exchange and the role of oxygen	4
S3.4 Breathing and health	2
S3.5 *Digestive system	4
S3.6 *Nutrition	5
S3.7 Food and energy	2
Review and evaluation	2
	24

Preamble

Through the study of this unit, students should become aware of the complexity of the living animal organism and also of the interdependence of body systems. Many animals whose physical characteristics are quite different from each other show surprising similarity in the ways in which they function.

The emphasis of this unit is on mammalian physiology and, in particular, on the respiratory and digestive systems of humans. Care should be taken, however, to develop a progressive and comparative animal-anatomy approach while studying these two systems. If desired, preserved animal specimens could be dissected in order to provide students with some experience in appropriate laboratory dissection techniques.

A locally developed unit may be designed to supplement the topics of this unit. Such a unit could further develop the ideas of food and energy, comparative anatomy, evolutionary anatomy, and other mammalian systems.

A brief review of animal characteristics is advisable before beginning this unit. Reference may be made to Characteristics of Living Things (Unit E1).

S3.1: Metabolism

The topic of metabolism could be introduced by recalling and briefly discussing the many activities, both physical and chemical, that take place continuously in animals. A description of such activities can lead to a study of energy interrelationships and an understanding of the processes of metabolism, catabolism, and anabolism.

These processes can be exemplified by a review of photosynthesis and respiration. The fact that glucose stores light energy as chemical energy should be recalled. The release of energy by burning can be compared to cellular respiration. A contrast could be drawn between photosynthesis and respiration, and this could be further studied.

Suggested terminology: *metabolism, anabolism, catabolism, cellular respiration.*

S3.2: Breathing systems

Although very diverse in appearance, functioning animals have basically the same kind of organization and, to some extent, similar structures to assure a system of gaseous exchange. A brief survey of the breathing systems (using charts, models, and/or preserved specimens) in small animals of several different phyla could lead to a good understanding of the structures and functions of these systems.

Students could name and describe such breathing structures as trachea, bronchioles, alveoli, pleurae, and the diaphragm. The path of oxygen could be traced from the atmosphere to the alveoli. Protective devices of the respiratory tract, such as coughing, sneezing, and mucus formation, could be mentioned here. The movement of oxygen from the alveoli to the cells by way of the circulatory system and the reverse action of carbon dioxide could be treated lightly.

Models are very useful in describing the functioning of the parts of the breathing system. The mechanics of inhaling and exhaling air should be understood.

Suggested terminology: *inhalation, exhalation, bronchioles, alveoli, pleurae, diaphragm.*



S3.3: Gas exchange and the role of oxygen

Students can discuss the major components of the atmosphere in terms of their approximate percentage concentrations. Investigations could be outlined to suggest how some components of the air can be detected. It is to be hoped that much discussion could derive from the students' general knowledge.

Students might perform an investigation to show that limewater is a good indicator for carbon dioxide and that some other commonly occurring gases do not produce a similar reaction. Other carbon-dioxide indicators, such as calcium bicarbonate and bromthymol blue, could be studied incidentally as part of this investigation.

Student experiments to study exhaled air are also recommended. How could students use a burning candle to show qualitatively that exhaled air contains both oxygen and carbon dioxide? A quantitative analysis of atmospheric and exhaled air for carbon dioxide and oxygen is suggested for enrichment of this topic. Some students might be permitted to demonstrate that animals, as well as humans, exhale carbon dioxide.

The importance of a healthy, well-developed breathing system to provide oxygen for respiration in living organisms should be discussed. Students should understand that, in the presence of sufficient oxygen, glucose can be completely oxidized to form carbon dioxide and water. Students might consider the following questions: What happens when cellular oxygen runs out? How does the process of fermentation produce alcohol? Why is alcohol used as a fuel?

Students should understand that in respiration some of the stored energy is given off as heat and some energy is transformed into chemical energy in a substance called adenosine triphosphate (ATP). The role of ATP as a carrier of chemical energy that living cells can use could be discussed at the discretion of the teacher.

This topic could be summarized by constructing a diagram of a cycle showing the interrelationships between photosynthesis and respiration in terms of carbon dioxide, water, oxygen, and organic substances. Summary word equations for photosynthesis and respiration are suggested to complete the topic.

Suggested terminology: *fermentation, adenosine triphosphate (ATP), oxidation, photosynthesis, respiration.*

S3.4: Breathing and health

Through the use of films, filmstrips, and newspaper and magazine articles, students could describe some of the changes in the body that can be attributed to health hazards such as smoking, dust particles, and asbestos fibres, and could relate some of the evidence that connects these causes to health problems.

Students could discuss the concerns of governments, unions, companies, and employees towards such health hazards and some of the actions that are taken to alleviate or resolve the problems.

Students could perform, or at least describe, the mouth-to-mouth method of artificial resuscitation. This would be a very worth-while review for those students who are aware of this method and a valuable and practical learning situation for those who are not.

Suggested terminology: *mouth-to-mouth resuscitation.*

S3.5: Digestive system

Students could approach this topic by comparing the different types of digestive systems that are found in various organisms (from the "simpler" to the more "complex" and terminating with the human digestive tract). They could compare and contrast such features as the lengths, surfaces, and associated structures of different systems. They should be able to identify the various parts of the alimentary canal of humans and have a good understanding of the main function of each part.

Some investigations should be performed by students to enable them to understand key digestive processes. They can compare the movement of substances across a membrane, by using some dialysis tubing and several solutions.

Students can be exposed to the concept of enzyme action and how under certain conditions specific enzymes break certain substances down into simpler ones that are diffusible into the blood. Students can do experiments to investigate the action of saliva on starch by using the iodine test and the Benedict's reagent test.

Suggested terminology: *alimentary canal* and its parts, *dialysis, enzymes, saliva.*

S3.6: Nutrition

It is suggested that the treatment of this topic be of a survey nature to include the basic essentials of nutrition. Time may not permit a full coverage of all groups of nutrients.

Nutrition is an important consideration in the maintenance of good health. If they are to be useful and available to body cells, nutrients must enter the cell in a suitable form through the cell membrane.

It is important, therefore, that students understand initially that the term "digestion", in the most general sense, implies the processes that convert complex organic substances into less-complex ones.

Students should know that foods are substances that yield energy, build tissues, or regulate body functions. They can classify foods into six chemically and functionally different groups — carbohydrates, lipids, proteins, water, minerals, and vitamins.

Students may examine a model of the glucose molecule and identify glucose as a monosaccharide using Benedict's or Fehling's reagent test. Students can then test various foods for a monosaccharide. The formation of a disaccharide from its monomers and the reverse reaction can be simply explained using block diagramming. Similarly, the general structure of starch and cellulose can be recognized. Starch can then be identified using the iodine test. The functions of carbohydrates, as they relate to adolescents in particular, can be discussed and summarized.

Students should understand the importance of proteins to all living organisms and should be able to explain the variation in organisms in terms of the sequencing of the amino acids that make up a variety of proteins. Insulin can be used as an example to show this sequencing. Through simplified block diagrams, students can be shown the chemical nature of an amino acid and a dipeptide. Proteins can be identified in foods, using a chemical test. The importance of proteins to all living organisms should be discussed.

Fats, vitamins, minerals, and water can be studied in a similar manner. Questions such as the following might be considered: How can fats be identified in foods? What are the major sources of, and the diseases caused by a deficiency of, the nutritionally important vitamins? What is the biological role of such minerals as potassium, sodium, calcium, phosphorus, iodine, and iron? What is the function of water in nutrition?

Suggested terminology: *nutrition, nutrient, digestion, carbohydrates, monosaccharide, lipid, disaccharide, protein, amino acid, dipeptide, fat, mineral, vitamin.*



S3.7: Food and energy

This topic can be introduced by reviewing the general definition of energy. Food energy can then be related to potential chemical energy. Students can investigate the energy released as various food components such as fat are oxidized, forming carbon dioxide and water. How could this investigation be carried out using Brazil nuts? Note that the word "combustion" is used as an alternative term for rapid oxidation and should not be confused with the term "cellular respiration".

Other energy investigations that can be carried out by students include the following:

- the calculation of the energy yields of foods high in carbohydrates, protein, and fat and a comparison of the values obtained;
- the determination of the energy requirements to perform various student activities, such as running for 30 min or sitting quietly for an hour;
- the calculation of the nutritional value of various student diets in terms of the energy content of the nutrients.

Students might like to try problems such as the following: A boy eats a piece of cherry pie that has an energy value of 1600 kJ. He returns to his apartment and decides to work off a large portion of this energy. He walks up 24 flights, each 3 m high, to his apartment. His mass is 60 kg and the gravity-mass ratio is 10 N/kg.

- What per cent of the pie's energy do you think the boy used up in climbing the stairs against the force of gravity?
- What per cent did he actually use? (only 2.7%)

Solution to part (b):

$$\begin{aligned} \text{Work done against gravity} \\ &= 60 \text{ kg} \times 10 \text{ N/kg} \times 24 \text{ (3 m)} \\ &= 43\,200 \text{ N}\cdot\text{m} \\ &= 43.2 \text{ kJ} \end{aligned}$$

Percentage comparison of work done to food energy

$$= \frac{43.2 \text{ kJ}}{1600 \text{ kJ}} \times 100\% = 2.7\%$$

Students should come to an appreciation of the nutritional value of common foods and the extent of the world's food problems during the discussions and activities of this topic.

Suggested terminology: *chemical energy, combustion, kilojoule.*

UNIT S4: GREEN PLANTS

In this core unit, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic in the unit.

Topics	Number of Periods
S4.1 Plant community	1
S4.2 *Role of green plants	0.5
S4.3 *Photosynthesis	4
S4.4 Equation for photosynthesis	0.5
S4.5 *Absorption	2
S4.6 Diffusion and osmosis	1
S4.7 Conduction	1
S4.8 *The leaf	3
S4.9 Ecological role of plants	2
S4.10 *Humans and plants	2
Review and evaluation	2
	19

Preamble

Through the study of this unit, students should develop an understanding of the relationship between plant structure and function and gain a fuller understanding and appreciation of the role that plants play in our world. This unit focuses on the green plant and its major contributions to the biosphere — the production of food and fibre and the release of oxygen as a result of photosynthesis.

It is suggested that students work with a variety of specimens; apparatus for experimentation, such as the compound light microscope; audio-visual materials; and student-prepared and commercially prepared slides and film loops. Reference may be made to Plants (Unit E15) and Populations and Communities (Unit S7). These offer suggestions regarding the presentation of material on the green plant's role in the cycle of photosynthesis and respiration.

S4.1: Plant community

From their past experience and current observation, students might be asked to identify a variety of plants in their environment. Taxonomic keys are often helpful in pointing out the diversity of plants. Such observation could help students to distinguish between green plants and non-green plants, between heterotrophs and autotrophs, and, finally, to realize that green plants are autotrophs.

Suggested terminology: *autotroph*, *heterotroph*, *taxonomic key*.

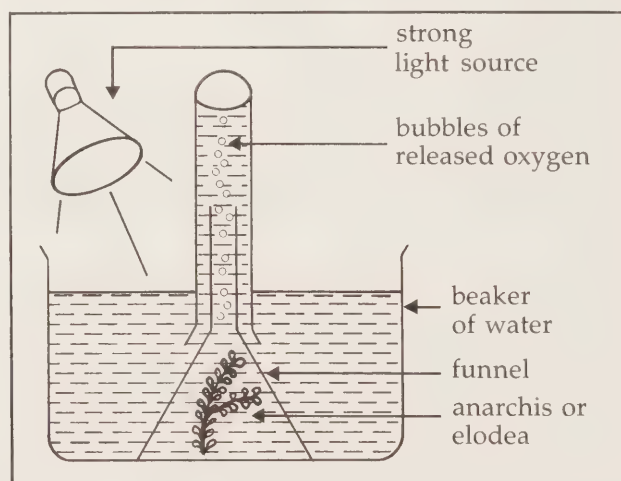
S4.2: Role of green plants

Students should be able to suggest several ways in which green plants are important to people. These might include their use as a source of food; their release of oxygen to the atmosphere; their use as medicinal herbs; the use of wood for fuel, paper production, and lumber; their use in such products as rubber, resin, and fibres; and certainly their existence as a source of beauty.

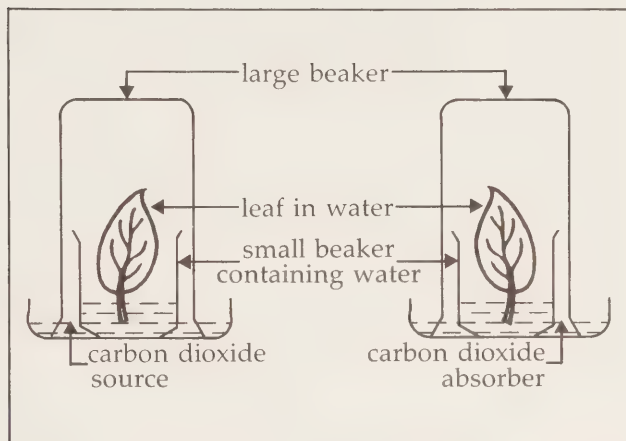
S4.3: Photosynthesis

Since photosynthesis (see Topic S1.4) is the most extensive chemical process on earth, the relationship between the structure of the green plant and the process of photosynthesis should be investigated through a variety of activities, which might include investigations such as the following:

- Show that light is required for photosynthesis. This might be done by covering both sides of a portion of a leaf with black paper and later testing for the presence of starch (Lugol's stain). *Note: The chlorophyll should be removed by boiling the leaf in alcohol in a water bath to ensure that the colour change of the iodine test can be easily seen. It is strongly recommended that the teacher perform this part of the procedure. A laboratory hot plate provides more control of the heating process than does a Bunsen burner.*
- Show that a gas (oxygen) is given off during photosynthesis and test for its identity. Refer to the accompanying diagram.



- Show that chlorophyll is required for starch production. This may easily be done by using variegated leaves from a coleus plant and testing for starch by using Lugol's stain.
- Show that a gas (carbon dioxide) is required for photosynthesis. Sodium bicarbonate solution may be used as a source of carbon dioxide and calcium hydroxide as an absorber of carbon dioxide (control).



Any investigations carried out should be used to emphasize the need for appropriate variables and controls. Both formal and informal reports might be expected from the students. The following questions might be posed: Why is it necessary to remove the chlorophyll from the leaves before making the starch test in the first investigation? Why should the plants in the second investigation be kept in the dark for 24 h before beginning the experiment? How might one test to see which gas is released during photosynthesis? What is the importance to living organisms of the release of this gas? What other substance, besides carbon dioxide, might one test for as an indication of photosynthesis?

Suggested terminology: *control, variable, chlorophyll, Lugol's stain, starch.*

S4.4: Equation for photosynthesis

From investigations and resource materials, students could be expected to identify the reactants and products of photosynthesis. They could review, or be introduced to, the writing of a chemical or word equation for photosynthesis. (See also Topic S1.4.)

Suggested terminology: *reactant, product, chemical equation.*

S4.5: Absorption

Once students have investigated and/or been provided with demonstrations to determine the reactants and products of photosynthesis, they might hypothesize on how plants are designed to obtain the substances (raw materials) to make glucose. (See also Topic S1.8.)

Students should be provided with a variety of materials to observe, such as germinating radish or

grass seedlings, prepared slides of a cross section of a root, the root system of a grass plant, and the taproot of a carrot. The structure and function of the tissues of fibrous roots and taproots and the structure and function of root hairs should be studied.

With the aid of resource materials and prepared cross sections of a root, students may become familiar with the structure and function of the specialized tissues of the root. The distinction between monocotyledonous and dicotyledonous roots may be made.

Suggested terminology: *fibrous root, taproot, root hair, epidermis, xylem, phloem.*

S4.6: Diffusion and osmosis

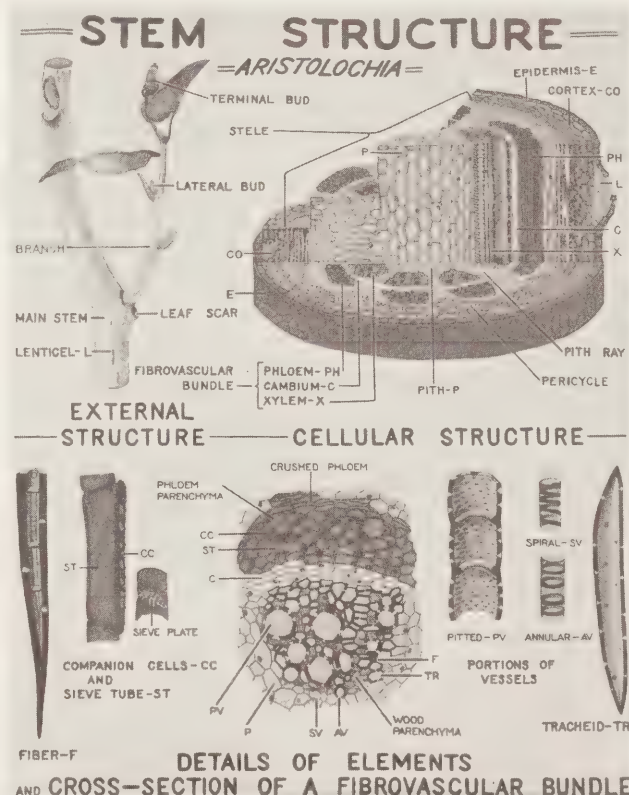
Through the use of dialysis tubing as a selectively permeable membrane, the osmosis of water may be observed. Students might be asked to suggest how a plant root-hair cell is similar to the osmometer in the demonstration (see Unit S1: Cells and Their Processes).

Suggested terminology: *osmosis, diffusion, solute, solvent, differentially permeable membrane.*

S4.7: Conduction

Floral dyes may be used to demonstrate the movement of water through the conducting tissue. Further study of conducting tissue might involve the use of prepared slides of stems or student-prepared cross sections of stems. Iodine can be used to stain for starch and phloroglucinol for lignin (found in support cells).

Suggested terminology: *vascular bundle, epidermis, cortex, pith.*



S4.8: The leaf

By observing both a growing plant with numerous leaves and a cross section of a leaf under a microscope, students should be able to suggest ways in which the leaf of a plant is designed to ensure that photosynthesis occurs. Students could be expected to describe the leaf's roles in terms of absorption of light (chloroplasts), transportation of water (veins), and diffusion of gases (stomata). Stomata may be observed under the microscope by preparing a wet mount of the lower epidermis of bryophyllum. If salt water is added to the slide, the closing of the stomata may be observed. When the salt water is replaced by distilled water, the stomata will open.

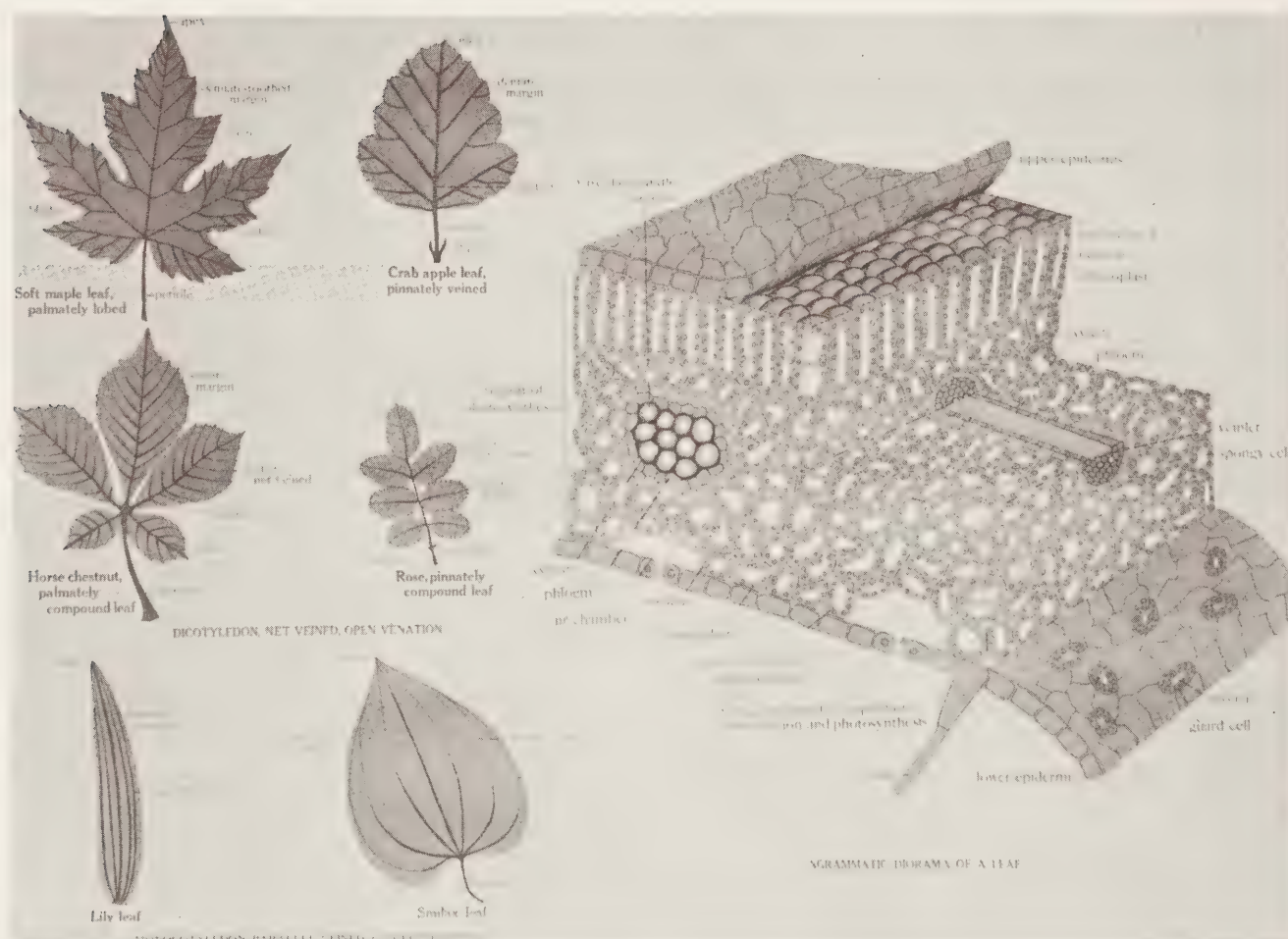
Suggested terminology: *lower and upper epidermis, palisade cells, spongy cells, xylem, phloem, stoma, stomata, guard cells, chloroplast, vein.*

S4.9: Ecological role of plants

The emphasis should be placed on the relationship between photosynthesis and respiration. Reference might be made to Interdependence of Living Things (Unit E4) and to Topic S7.10: Cycling of Matter. The following facts should be stressed: that plants provide chemical potential energy in the forms of glucose and starch; that oxygen is necessary for the aerobic respiration of plants and animals; and that such plants as legumes are involved in the fixation of nitrogen.

S4.10: Humans and plants

Some of the applied sciences, such as horticulture, greenhouse, agriculture, forestry, landscape architecture, and microgardening, could be surveyed to see which plant species are cultivated, harvested, and improved. The use of films, film loops, and guest lecturers from a variety of these professions and industries could provide some clarification of, or a redefinition of, society's goals for our forests, agricultural land, and recreational and urban areas.



UNIT S5: HEAT

In this core unit, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic in the unit.

Topics	Number of Periods
S5.1 Thermal expansion (review)	1
S5.2 Heat transfer (review)	1
S5.3 Changes of state	1
S5.4 Early theories of heat	1
S5.5 Particle nature of matter	1
S5.6 *Quantity of heat	2
S5.7 *The joule	1
S5.8 *Specific heat capacity	1
S5.9 Method of mixtures with water	3
S5.10 Specific heat capacity of metals	2
S5.11 Heat of fusion of ice	2
S5.12 Heat of vaporization of water	2
Review and evaluation	2
	20

Preamble

We live in a world where non-renewable sources of energy are decreasing at an ever-increasing rate, and heat in particular seems to be in great demand. Since heat energy is of great significance to our everyday lives, students should have an awareness of its properties and of how it is measured.

Students should understand the definitions of work and energy and how these are measured mechanically (See Unit E3: Force and Energy). Reference should also be made to Topic S17.10: Energy, since the fact that a joule is equal to a watt second could be useful.

The kinetic molecular theory can be used throughout this unit to introduce or review explanations of thermal expansion, heat transfer, temperature changes, and changes of state. This theory can act as a unifying theme for the unit. Such topics as quantity of heat, specific heat capacity, the principle of heat exchange, and latent heat should be studied quantitatively using problem-solving as a means to better understanding. Because of the conceptual difficulties and the mathematical work involved, it is advisable, perhaps, to reserve this unit for the final year of the Intermediate Division science program. Students should then be more at ease with solving equations and dealing with fairly abstract work. In any event, problems should be set at a reasonable level so that they are attainable by the majority of students.

Throughout this unit, the teacher should point out the role that various properties of heat play in our lives. In this regard, if students are ever to make an analysis of heat-energy use, they will need to understand how heat is measured in joules. The common metric unit, the calorie, is not to be used except, possibly, to mention that it is now obsolete and equivalent to 4.2 J. For the information only of teachers who have been accustomed to using calories, data in former texts should be converted by means of the relation $1 \text{ cal} = 4.2 \text{ J}$.

In the Intermediate Division, it is inappropriate to use the SI base unit of temperature, the kelvin. The degree Celsius ($^{\circ}\text{C}$) should be used to express both temperature and temperature interval. The Celsius degree ($^{\circ}\text{C}$) for temperature change is obsolete.

The unit to be used for specific heat capacity is the joule per kilogram degree Celsius, symbolized by $\text{J}/(\text{kg}\cdot^{\circ}\text{C})$. The unit for latent heat is the joule per kilogram (J/kg). The formula symbol for quantity of heat energy is usually Q (although E may be used); for specific heat capacity, c ; and for latent heat, l . The qualifier "specific" means "per unit mass".

The teacher must plan this unit very carefully as the timing is critical. There may be entirely different objectives for general- and advanced-level students. Those students who are going on to take Senior courses in chemistry, biology, and physics need to grasp the principle of energy transfer and to be able to solve related problems. For many other students, a strong emphasis on mathematical work may not be needed. A suitable balance between practical activities and problem-solving must be determined by the teacher.

S5.1: Thermal expansion (review)

There should be a brief review of the fact that most materials expand when heated (there are exceptions). Well-prepared demonstrations to show that a metal expands slightly, water considerably, and air very extensively would be particularly useful for students who have not studied Heat and Temperature (Unit E10). Individual students can participate in such demonstrations, which, if carried out in sequence, should clearly show the comparison between the expansion rates of the three substances.

Conclusions regarding the expansion of solids, liquids, and gases based on this scant evidence must be made rather cautiously.

Time may permit the demonstration and discussion of the fact that different metals expand at different rates and that we make use of this phenomenon in the bimetallic strip or coil used in thermostats and some thermometers.

Suggested terminology: *thermal expansion and contraction, bimetallic strip, thermostat.*

S5.2: Heat transfer (review)

Through simple but rather fast-moving demonstrations, students can “see” or “feel” that heat can be transferred from one point to another by conduction, convection, or radiation. Although this treatment may be somewhat hurried for students who have not studied Heat and Temperature (Unit E10), there is no need at this juncture to elaborate on these concepts. Students have an intuitive consciousness of conduction; they will meet convection elsewhere in this program and in atmospheric studies in geography; and they will study radiant effects in other parts of biology and physics.

The important issue here is to deal with the three methods of heat transfer and to explain them later in terms of particles or radiant energy, where possible.

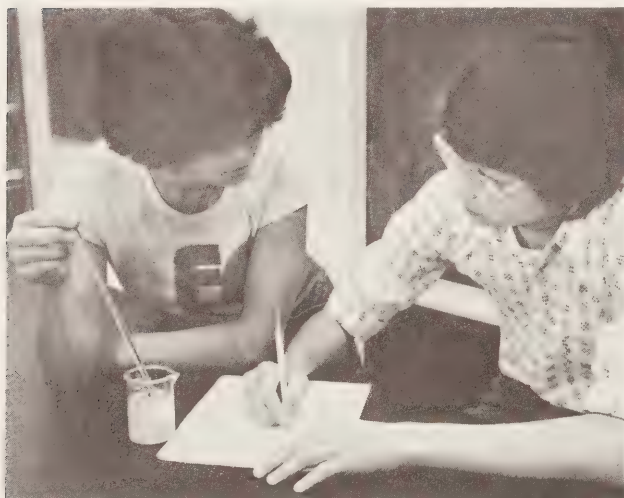
Suggested terminology: *conduction, convection, radiation.*

S5.3: Changes of state

From their experience, students know that it takes heat to melt ice – heat from the sun, warm air, a flame, and so on. They should be able to express this process in a simple word equation: ice + heat $\blacktriangleright$ water (during melting).

When water is placed in a freezer, what happens and what would the corresponding statement be? The students should arrive at: water – heat $\blacktriangleright$ ice (during freezing).

Similarly, they can deduce that: water + heat $\blacktriangleright$ steam (during boiling) and steam – heat $\blacktriangleright$ water (during condensation).



Perhaps it would be more appropriate to use the expression “heat energy” rather than just “heat”.

In this study, it should be pointed out that for water melting and freezing occur at 0°C and boiling at 100°C; this means that although quantities of heat energy are involved, the temperature is unaffected during the change of state. Thus, “quantity of heat” is not “temperature”.

Students should be able to form generalizations, such as “For substances that melt (at a fixed temperature) solid + heat $\blacktriangleright$ liquid (during the melting process).”

Suggested terminology: *melting, fusion, freezing, solidification, boiling, condensation.*

S5.4: Early theories of heat

This topic could be treated as a reading assignment or a debate in order to help students understand change of state, thermal expansion, and heat transfer. Students could be made aware of the “caloric theory” of heat. They should realize that this is an example of a scientific theory that was useful because it explained many properties of heat, for instance, ice + caloric $\blacktriangleright$ water.

Although the “particle theory” was introduced by early Greek philosophers, it was ignored for centuries. The contributions, in comparatively recent times, by Antoine Laurent Lavoisier, Joseph Priestley, Benjamin Thompson (Count Rumford), Sir Francis Bacon, James Joule, and Joseph Black to the caloric and particle theories should be of interest to the students. A detailed development of this evolving system of thought is not necessarily applicable here, since some of these ideas are contained in the work in other units.

Suggested terminology: *caloric theory, particle theory.*

S5.5: Particle nature of matter

Students should realize that matter is supposedly made up of particles (molecules and atoms) that have energy and are constantly moving. Various phenomena can be explained by this kinetic molecular theory. Different groups of students might theorize separately and then compare their ideas on such matters as “What happens in terms of molecules when:

- the temperature of a substance is raised?”
- a solid, a liquid, or a gas expands due to heat?”
- a metal conducts heat whereas air is comparatively ineffectual?”
- a gas such as air convects heat while metals don’t?”
- a solid melts into a liquid?”
- a liquid boils into a vapour?”

Suggested terminology: *molecules, atoms, kinetic molecular theory.*

S5.6: Quantity of heat

Students should know that temperature is the measure of the “hotness” or “coldness” of a body, and that a body’s temperature will drop in cooler surroundings or rise in warmer surroundings. The temperatures of two adjacent regions will indicate the direction in which heat energy will “flow” out of one region and into the other. Temperature is an indication of a heat-activity level and may be thought of as related to the average kinetic energy of the molecules in the substance. Temperature, however, is not energy; it is measured in degrees Celsius.

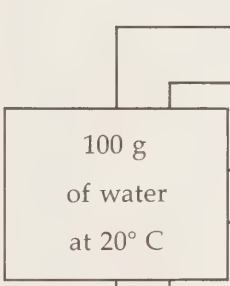
Quantity of heat energy, on the other hand, is an amount of energy that flows from one body to another due to a difference in temperature levels. The transfer of heat energy to a body raises its total internal energy. An increase in the average kinetic energy of the molecules causes a temperature rise. Sometimes when a body is heated, the temperature does not rise, as is the case during a change of

state; the potential energy of the molecules increases.

Upon what factors does the quantity of heat energy transferred depend? Suppose that 100 g of water at 20°C are to be warmed up by adding more matter. Which will raise the original water’s temperature more:

- an additional 100 g of water at 60°C or an additional 100 g of water at 80°C?
- an additional 100 g of water at 60°C or an additional 200 g of water at 60°C?
- an additional 100 g of water at 60°C or an additional 100 g of aluminum at 60°C?

An experiment could be carried out with different groups of students doing different parts. They should estimate to what temperature they think the original 100 g of water will be raised in each case. Three pairs of teams can deal with one variable each. The six “original” amounts of water should all be measured at about the same time from the same pail of water at 20°C. The results may be tabulated as follows:

Original substance	Additional substance added to supply heat	Final temperature to which original is raised	
		Estimate	Measured
	100 g of water at 60°C	40°C	38°C
	100 g of water at 80°C	50°C	47°C
	100 g of water at 60°C	40°C	36°C
	200 g of water at 60°C	45°C	44°C
	100 g of water at 60°C	40°C	37°C
	100 g of aluminum at 60°C	30°C	34°C

The factors that affect the quantity of heat transferred by the addition of a substance may also be tabulated.

Suggested terminology: *temperature, quantity of heat.*

Factors governing the quantity of heat	Theoretical explanation in terms of molecules
Temperature of the substance	The higher the temperature, the more active the molecules.
Mass of the substance	The greater the mass, the more the total molecular energy.
Type of substance	Different kinds of molecules have different levels of activity

S5.7: The joule

Students have learned that a quantity of heat, whether gained or lost, is energy, and in SI energy is measured in joules. (The use of the calorie should be avoided.)

If Topic S17.10: Energy has preceded this unit, the students will know that a joule is equal to a watt second. An immersion heater can be used to heat some water to establish an important relationship: that the heat energy absorbed by water is related to its mass and temperature change. The question that may now be asked is: "What does the addition of heat energy do to the temperature of a kilogram of water?"

An activity giving data such as the following may be carried out. One kilogram of water is heated from 23°C to 35°C by a 200 W heater, taking about 4.2 min. The pertinent data may be listed as follows:

Power:	$P = 200 \text{ W}$
Time elapsed:	$t = 4.2 \text{ min} = 252 \text{ s}$
Energy supplied:	$E = Pt$ $= 200 \text{ W} \times 252 \text{ s}$ $= 50\,400 \text{ J}$
Mass of water:	$m = 1 \text{ kg}$
Temperature change:	$\Delta T = 35^\circ\text{C} - 23^\circ\text{C} = 12^\circ\text{C}$

$\therefore$ 1 kg of water was raised through 12°C by 50 400 J.

$\therefore$ 1 kg of water was raised through 1°C by 4200 J.
Conclusion: 4200 J will raise 1 kg of water through 1°C.

If students have not been introduced to the fact that a joule equals a watt second, they may have to be told the results of the above experiment. This particular set of data shows ideal results. In an actual experiment, unwanted sources of heat loss or gain may be listed.

Note: There is no more need to define the joule as the amount of heat energy needed to raise 0.24 g of water through 1°C or to raise 1 g of water through 0.24°C any more than we define the metre as the distance an object falls from rest at sea level in 0.4516 s. The joule is simply a newton metre as defined in physics.

Suggested terminology: *joule, watt second.*

S5.8: Specific heat capacity

The activity mentioned in the last topic may be carried out by heating a kilogram of oil or some other convenient liquid such as ethylene glycol to see how much heat energy is required to raise the temperature of 1 kg through 1°C. Then a listing of substances may be given as follows:

4200 J will raise 1 kg of water through 1°C.
2400 J will raise 1 kg of ethyl alcohol through 1°C.
2500 J will raise 1 kg of methyl alcohol through 1°C.
140 J will raise 1 kg of mercury through 1°C.
(In this unit, it is inappropriate to deal with variations in these values at different temperatures.)

Students should then grasp the meaning of 4200 J/(kg•°C) for water. This quantitative property of water is called its specific heat capacity and is denoted in formulas by the letter c . Thus:

$$c_{\text{water}} = 4200 \text{ J/(kg}\cdot^\circ\text{C)}$$

$$c_{\text{mercury}} = 140 \text{ J/(kg}\cdot^\circ\text{C)}$$

Simple problems on quantity of heat should involve the formula $Q = mc \Delta T$, where Q is the heat energy transferred in joules; m is the mass in kilograms; c is the specific heat capacity in joules per kilogram degree Celsius; and ΔT is the temperature change in degrees Celsius.

Applications of substances that have high or low specific heat capacities may be discussed.

It may be inappropriate for some students in a general-level course to solve problems involving the formula stated above. However, the concept that different substances have different specific heat capacities is important.

Suggested terminology: *specific heat capacity.*

S5.9: Method of mixtures with water

Students know from everyday life that adding cold milk to hot chocolate cools it, or adding ice cubes to ginger ale lowers the temperature of the ginger ale. Having performed experiments in which cold water has been mixed with warm and the resultant temperature measured, students should now solve problems using the principle of heat exchange, namely, that the heat lost by the warmer water equals that gained by the cooler, that is, the total energy change is zero. Mathematically this principle is stated by the equation: $\Delta E_{\text{total}} = 0$.

The level of difficulty of the problems given to students should be geared to what may be reasonably demanded of them. The following sample problems are progressively more difficult. For each, the main equation in the solution is shown.

- 2 kg of cold water rise through 25°C when 5 kg of hot water are added. Through what temperature interval did the hot water drop?

$$2 \text{ kg} \times c_{\text{water}} \times 25^\circ\text{C} = 5 \text{ kg} \times c_{\text{water}} \times \Delta T$$

(Answer: 10°C)

- 2 kg of cold water receive 42 kJ of heat energy by the addition of some hot water. What is the temperature increase in the cold water?

$$42\,000 \text{ J} = 2 \text{ kg} \times \frac{4200 \text{ J}}{\text{kg}\cdot^\circ\text{C}} \times \Delta T$$

(Answer: 5°C)

- 700 g of water at 30°C are mixed with 1.7 kg of water at 78°C. What is the resulting temperature?

$$0.7 \text{ kg} \times \frac{4200 \text{ J}}{\text{kg}\cdot^\circ\text{C}} \times (T - 30^\circ\text{C})$$

$$+ 1.7 \text{ kg} \times \frac{4200 \text{ J}}{\text{kg}\cdot^\circ\text{C}} \times (T - 78^\circ\text{C}) = 0$$

$$\text{Hence, } 0.7(T - 30^\circ\text{C}) + 1.7(T - 78^\circ\text{C}) = 0$$

(Answer: 64°C)

- What is the resulting temperature when 1200 g of water at 30°C, 800 g at 80°C, and 4.0 kg at 50°C are mixed?

$$1.2 \times 4200 (T - 30^\circ\text{C}) + 0.8 \times 4200 (T - 80^\circ\text{C}) + 4.0 \times 4200 (T - 50^\circ\text{C}) = 0$$

(Answer: 50°C)

Suggested terminology: *principle of heat exchange*, ΔE_{total} .

S5.10: Specific heat capacity of metals

An experiment such as the following could be conducted to determine the specific heat capacity of a metal: 400 g of lead pellets are heated in a test tube that is placed in boiling water for about 6 min. The pellets are assumed to be at 100°C. 140 g of water are measured into a styrofoam cup, which may be assumed to have a water equivalent of 10 g. Hence, 400 g of lead will mix with the equivalent of 150 g of water. The initial and final temperatures of the water and the water-lead mixture are 17°C and 23°C respectively. Since $\Delta E_{\text{total}} = 0$, then the heat change in the water + the heat change in the lead = 0. Hence,

$$0.15 \text{ kg} \times \frac{4200 \text{ J}}{\text{kg}\cdot^\circ\text{C}} \times (23-17)^\circ\text{C} + 0.4 \text{ kg} \times c \times (23-100)^\circ\text{C} = 0$$

$$\therefore (0.15 \times 4200 \times 6) \text{ J} = 0.4 \text{ kg} \times c \times 77^\circ\text{C}$$

From this equation, $c_{\text{lead}} = 1.2 \times 10^2 \text{ J}/(\text{kg}\cdot^\circ\text{C})$. The actual value is about 130 J/(kg·°C).

S5.11: Heat of fusion of ice

An experiment could be conducted to determine the amount of heat required to melt a kilogram of ice. Students may suggest ways to do this: either by direct heat using an immersion heater or by the method of mixtures. Again, styrofoam cups can be used. The important point here is that the heat energy is used to change the solid ice to liquid water rather than to change the temperature. The



quantitative value of the latent heat of fusion of ice should be taken as 334 kJ/kg. Simple problems involving this value should be given. For example: An ice cube at 0°C, having a 30 g mass, sits in a bowl. After some time it has become water at room temperature (20°C). How much heat was transferred to the ice cube to change it to water at 20°C?

$$\begin{aligned} \Delta E &= ml_F + mc\Delta T \\ &= \{0.030 \text{ kg} \times 334 \text{ kJ/kg}\} \\ &\quad + \{0.030 \text{ kg} \times 4200 \text{ J}/(\text{kg}\cdot^\circ\text{C}) \times 20^\circ\text{C}\} \\ &= 10.02 \text{ kJ} + 2520 \text{ J} \\ &= 10.02 \text{ kJ} + 2.52 \text{ kJ} \\ &= 13 \text{ kJ (approx.)} \end{aligned}$$

Note: The symbol l is conventionally used for specific latent heat. Then, l_F may be used for the specific latent heat of fusion and l_V for vaporization. The term “specific” denotes “per unit mass”, and in SI the unit mass is generally taken as the kilogram.

While dealing with melting and freezing of water, students may find it interesting to measure the temperature of water only to find out that it is, say, -5°C. Why is it below 0°C and not frozen? This “water” is an aqueous solution of table salt. If a student tastes the “water” (with permission of the teacher) he or she will report that it is salt water. Why does adding salt lower rather than raise the freezing point? Any speculation, or is this just “nature”? This could be left as an open unanswered question – something to wonder about.

Suggested terminology: *latent heat*, *specific latent heat*, *heat of fusion*.

S5.12: Heat of vaporization of water

Without actually measuring the specific latent heat of vaporization, do you think it requires more heat to melt 50 g of ice or to vaporize (at 100°C) 50 g of water? An experiment could be designed where a couple of ice cubes in a test tube are melted and then the resulting water boiled away. The changes of state are timed for comparison. The change from water to steam should take about six or seven times as long as the change from ice to water.

The specific latent heat of vaporization of water is 2250 kJ/kg. Simple problems involving this value could be worked out.

If time permits, other questions that could be asked include:

- Do solutes such as salt raise or lower the boiling point of water?
- Does the atmospheric pressure affect the boiling point of water? Its heat of vaporization?
- Why is a steam burn more serious than a hot-water burn?
- How much heat is needed to slowly evaporate a kilogram of water?
- What is the importance of the high heat of vaporization of water to us?

Suggested terminology: *specific latent heat of vaporization*.

UNIT S6: MEASUREMENT

In this core unit, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic in the unit.

Topics	Number of Periods
S6.1 *Length	2
S6.2 *Speed	1
S6.3 Area	1
S6.4 *Volume	2
S6.5 Length, area, and volume	2
S6.6 *Mass	1
S6.7 Conservation of mass	1
S6.8 *Mass and volume	2
S6.9 Concept of density	2
S6.10 *Measurement of density	2
S6.11 Density problems	2
S6.12 Applications of density	2
Review and evaluation	2

22

Preamble

Before teaching this unit, teachers should read Appendix A on SI units.

Through their study of this unit, students should develop an understanding of some quantitative properties of matter. Since measurement has been an on-going topic, it is important to avoid wasting time on unnecessary repetition of work already grasped by the students. Reference should be made to Measurement (Unit E5).

Stress should be placed on the idea that in SI there is a single preferred or primary unit for each physical quantity: metre for length, square metre for area, cubic metre for volume, kilogram for mass, second for time, metre per second for speed, kilogram per cubic metre for density, and so on. These primary units are either SI base units or coherent derived units. All other units used to measure these quantities are multiples or submultiples of the primary units and may be referred to as secondary units. This distinction lays the ground work for later courses in science where primary units are substituted in formulas because they reduce conversion factors to a minimum. This unit of study emphasizes quantitative work and, therefore, involves students in a variety of calculations. This should strengthen their skills in problem-solving, which is an important feature of the unit.

The refinement of measuring techniques, the search for quantitative data, the production of graphs, the evaluation of the suitability of volume or mass as a measure of matter, the forming of well-organized and logical mathematical solutions, the understanding of a measurement system, and a deeper appreciation of the characteristics of matter are among the objectives and experiences that students will be exposed to in this unit.

S6.1: Length

Students should have some appreciation of the range of length units from the micrometre to the megametre. No reference should be made to the micron except to state that it has been replaced by the micrometre. The prefixes micro to mega and their corresponding power-of-ten notation should be understood.

The procedures for rounding off to an appropriate number of significant digits should become an integral part of this unit. As well, students should be able to appreciate the linear dimensions of specimens seen under a microscope. If students are not aware of the phenomenon of parallax, it should be discussed.

Suggested terminology: *micro, milli, centi, deci, kilo, mega, exponent, power of ten, rounding, significant digit, magnification, parallax.*

S6.2: Speed

The primary SI unit of speed is the metre per second; it is a unit that will be required in later courses, particularly for substitution in formulas that involve speed or velocity. (The study of velocity as a vector quantity is not required in this unit.)

Students should find the speed of various objects in any convenient metric unit; they should also be able to convert the speed to metres per second if it is not already expressed in this preferred form. For example, they should be able to convert a speed in kilometres per hour to its equivalent in metres per second, as follows:

Problem: Convert 90 km/h to a speed in metres per second.

$$\begin{aligned}\text{Solution: } \frac{90 \text{ km}}{\text{h}} &= \frac{90 \text{ km}}{1 \text{ h}} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{3600 \text{ s}} \\ &= \frac{90\,000 \text{ m}}{3\,600 \text{ s}} \\ &= 25 \text{ m/s}\end{aligned}$$

Problems such as the following may be given: At 100 km/h along a multi-lane highway, how far does a motorist travel in 1 s? In 5 min? In 2.5 h?

Suggested terminology: *speed, metre per second, kilometre per hour.*



S6.3: Area

Metric area units, simple area formulas, and their applications should be reviewed. The determination of the area of an irregularly shaped surface should be encouraged. Given an acetate grid of centimetre squares, for example, students could be asked how it would assist them in finding the area of the sole of a shoe. How should they deal with those squares that lie on the boundary? Creative thinking should be permitted for those students who may not have been exposed to this technique. Some applications of the use of area should be discussed: for example, in determining the number of square kilometres in the surface of a lake, the number of colonies per square centimetre, the number of plants per square metre, or the number of trees per hectare.

Suggested terminology: *area, hectare, square metre, square centimetre, square kilometre.*

S6.4: Volume

Various methods for determining the volume of regular and irregular solids and the volume of liquids should be reviewed, and methods for determining the volume of a gas should be discussed. Using the downward displacement of water, students could determine their lung capacity.

Such questions as the following may be asked: Is volume additive? For example, does 50 mL of dry sand plus 50 mL of water add up to 100 mL when mixed? Does a jar of marbles plus a jar of water make two jars of mixture? Does the total volume of a piece of rock salt and the water it is immersed in remain constant as the salt dissolves? Do 50 mL of water plus 50 mL of alcohol equal 100 mL of solution? Students should be encouraged to make a prediction, propose a rationale, and then verify the result. The outcome may enable them to then modify their explanations. The inadequacy of volume as a reliable measure of quantity of matter should be discussed.

Throughout the work on volume, students should be conscious of the equivalence of the cubic centimetre and millilitre, the cubic decimetre and litre, and the cubic metre and kilolitre. For the work on density, it is important to be familiar with the fact that $1 \text{ m}^3 = 1000 \text{ dm}^3 = 1000 \text{ L}$.

Suggested terminology: *volume, meniscus, displacement, cubic metre, cubic decimetre, cubic centimetre, kilolitre, litre, millilitre.*

S6.5: Length, area, and volume

The work of some students may be enriched when length, area, and volume are interrelated. For cylinders and prisms, $V = Ah$, where V represents volume; A , the base area; and h , the height. Thus, $h = V/A$, and this may be used to determine the thickness of a film of oil and to obtain some idea of a molecular dimension. The volume (V) of a drop of oleic acid may be found by determining the volume of many drops. The area (A) may be determined by observing and measuring the film produced by one drop on the surface of water. If it is assumed that the drop has formed a cylindrical film, the thickness (h) of the film may be calculated. This gives an approximation of a dimension of a molecule.

S6.6: Mass

The use and care of the lever-type balance and the spring-type scale for determining mass should be familiar to students. Discuss the disadvantage of the spring scale for measuring mass when the altitude is changed. (The variation over the earth's surface in such a balance is less than 0.5%; however, if moved to the moon, recalibration of the balance would be required.)

The kilogram (with its submultiples and multiples), the gram, milligram, and megagram (tonne or metric ton) should be familiar to most students. The meaning of mass and its determination should also be discussed. Teachers should stress the principle that if A balances B , and B balances C , then no matter what their volumes may be, A , B , and C all have the same mass; that is, they contain the same quantity of matter.

Note: Allowance for the buoyant force of air need not complicate the issue at this stage.

Students should understand that mass is additive and, in contrast to volume, is a reliable measure of the quantity of matter.

Other concepts that should be illustrated include the following:

- different objects can have the same mass, but a wide range of volumes;
- different objects can have the same volume, but a wide range of masses.

A display of objects that demonstrate these ideas would be useful and may take some time to prepare; students can add to the collection over an extended period of time.

Suggested terminology: *mass, kilogram, gram, megagram, tonne, milligram.*

S6.7: Conservation of mass

Students may carry out activities to determine whether mass is conserved (a) during a physical change or (b) during a chemical change, as follows:

a) Several soda crackers are placed in a small flower pot which is placed inside a transparent plastic bag and secured with a twister. A physical change is brought about by breaking and crushing the crackers and by carefully smashing the pot with a hammer without rupturing the bag. The students are then asked to state those properties of the contents of the bag that changed and those that remained constant. The question of mass should arise. What evidence would be needed to determine if it was conserved? Should this be verified or left to reason alone?

b) The following experiment can be done to see whether mass is conserved during a chemical change. Two open vials containing clear solutions are placed upright in a jar which is then covered tightly with its lid. The bottle is shaken briefly to mix the solutions which react to form a precipitate. Again, the question of conservation of mass is posed. Need the mass be actually measured before and after the chemical reaction? Examples of initial solutions are barium nitrate and sodium sulphate or iron (III) chloride and sodium hydroxide. *Note: Students must be cautioned about the dangers of chemicals such as sodium hydroxide. Safety measures must be observed.*

Students can consider such situations as the following: Is mass conserved in a bonfire, the baking of a cake, the blowing up of a balloon, the preparation of a message in invisible ink, the magician's production of a rabbit from a hat, or the boiling of water? (See Topics S2.4 and S2.6.)

S6.8: Mass and volume

One way of establishing some kind of relationship between the mass and volume characteristics of a substance is as follows: Groups of students may be asked to determine the mass of four samples of a liquid such as brine, alcohol, antifreeze, or motor oil. Volumes, such as 50 mL, 150 mL, 200 mL, and 250 mL, are chosen to simplify comparisons. Opportunity should be given for students to develop good graphs of the mass-volume relationship. Students are not intended to work out the density at this point. From their graphs, students may then determine the mass of such volumes as 100 mL and 300 mL. The terms "interpolation" and "extrapolation" could be discussed as well as the assumptions or inferences made when interpolating or extrapolating.

The above procedure may be carried out with four blocks of wood or some other solid. "Convenient" dimensions would reduce the time spent in making comparisons. For example, the blocks may have the following dimensions:

$$\begin{aligned}2.0 \text{ cm} \times 5.0 \text{ cm} \times 5.0 \text{ cm} &= 50 \text{ cm}^3 = 5.0 \times 10^1 \text{ cm}^3 \\5.0 \text{ cm} \times 5.0 \text{ cm} \times 6.0 \text{ cm} &= 150 \text{ cm}^3 = 1.5 \times 10^2 \text{ cm}^3 \\4.0 \text{ cm} \times 5.0 \text{ cm} \times 10.0 \text{ cm} &= 200 \text{ cm}^3 = 2.0 \times 10^2 \text{ cm}^3 \\5.0 \text{ cm} \times 5.0 \text{ cm} \times 10.0 \text{ cm} &= 250 \text{ cm}^3 = 2.5 \times 10^2 \text{ cm}^3\end{aligned}$$

Students should be able to conclude that for a given (incompressible) liquid or solid:

- the mass increases as the volume increases;
- the volume increases as the mass increases;
- the mass is proportional to the volume or the volume is proportional to the mass;
- although the samples may have different volumes and masses, they all have some numerically measurable characteristic in common – the ratio of mass to volume or of volume to mass. This characteristic is a property of the substance and not just of a particular sample.

Suggested terminology: *interpolation, extrapolation, ratio, proportional.*

S6.9: Concept of density

Population densities are given as the quantity of people per unit area; for example, 180 people/km². The comparison to physical density may be made. "Density" is defined as "the quantity of matter per unit volume", that is, mass per volume. At this stage it is wise to avoid the density formula.

Examples from Topic S6.8 could be taken. Suppose the mass of 200 mL of oil were 180 g, then we could choose to find the corresponding mass of 1 mL or 1 L. Since Canada is adopting SI, it is recommended that 1 L would be the better choice. If 200 mL of oil has a mass of 180 g, then 1000 mL has a mass of 900 g. Thus, oil has a mass of 900 g for each litre, and its density is 900 g/L.

It is strongly recommended in SI that the predominant unit of density be the SI-derived unit – the kilogram per cubic metre (kg/m³). Thus, 900 g/L = 900 kg/m³, and this is why the litre was chosen over the millilitre in the above example.

The kilogram per cubic metre may also be introduced by posing such problems as the following:

- a) In an oil storage tank, the volume of the oil is 80 m³ and the mass 72 000 kg. What is the density of the oil?
Solution: 80 m³ of oil has a mass of 72 000 kg; thus, 1 m³ of oil has a mass of 900 kg. Hence, the density of the oil is 900 kg/m³ or $9.0 \times 10^2 \text{ kg/m}^3$.
- b) A large rock having a mass of 7800 kg is found to occupy 3.0 m³. What is its density?
(Answer: $2.6 \times 10^3 \text{ kg/m}^3$)
- c) A pile of coal has an overall volume of 10 m³, but 20% of this is known to be air space. What is the density of the coal if the mass of the pile is 19.2 t?
(Answer: $2.4 \times 10^3 \text{ kg/m}^3$)

The formula $D = m/V$ may be introduced as the concept of density is clearly grasped.

Students should realize that $1 \text{ g/L} = 1 \text{ g/dm}^3 = 1 \text{ kg/m}^3$. Hence, any density such as 900 g/L can be “automatically” switched to 900 kg/m^3 or vice versa.

Reference may be made to the former CGS preferred unit of density, the gram per cubic centimetre, but it should be de-emphasized since the preferred unit is the kilogram per cubic metre. Older texts will refer to 2.7 g/cm^3 for aluminum, rather than 2700 kg/m^3 . For this reason, students should be aware of this opportunity to emphasize the SI form. The kilogram per cubic metre is required for simplicity of substitution in formulas containing D (for density) in further courses in science.

Suggested terminology: *density, kilogram per cubic metre, gram per litre, gram per cubic decimetre.*

S6.10: Measurement of density

Students can determine the density of a liquid, in the preferred SI unit of density, by a method such as the following: A mass of 100 mL of alcohol is found to be 82.0 g . If 100 mL of alcohol has a mass of 82.0 g , then 1000 mL of alcohol has a mass of 820 g , or 1 L of alcohol has a mass of 820 g . Thus, the density of alcohol is 820 g/L or 820 kg/m^3 .

Having determined the dimensions and mass of a solid cuboid, such as a block of wood, plastic, or metal, students could determine the density in SI units, as follows: Suppose a block of wood $4.0 \text{ cm} \times 5.0 \text{ cm} \times 10.0 \text{ cm}$ is found to have a mass of 152 g . The volume is 200 cm^3 . Then, 200 cm^3 of wood has a mass of 152 g and 1000 cm^3 of wood has a mass of 760 g or 1 dm^3 of wood has a mass of 760 g . Thus, the density of the wood is 760 g/dm^3 or 760 kg/m^3 or $7.6 \times 10^2 \text{ kg/m}^3$.

Note: Students should be able to “automatically” interchange the symbols g/dm^3 and g/L and kg/m^3 and should know the justification for being able to do so.

S6.11: Density problems

From their laboratory work, students should be able to solve density problems to find the densities of irregularly shaped solids besides those of liquids and cuboids. A sample student report could read as follows:

Density of stone B

Mass of stone $= m = 394 \text{ g}$ by weighing

Volume of stone $= V = 171 \text{ mL}$ by displacement

Density of stone $= D = m/V$

$$= \frac{394 \text{ g}}{171 \text{ mL}}$$

$$= \frac{394 \text{ g}}{171 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}}$$

$$= \frac{394\,000 \text{ g/L}}{171}$$

$$= 2304 \text{ kg/m}^3$$

Density of stone B $= 2.30 \times 10^3 \text{ kg/m}^3$

Students who take this topic should become proficient in the use of the density formula. Given any two of the three quantities – density, mass, or volume – they should be able to calculate the third. The use of hand calculators should be encouraged.

The student’s understanding of the meaning of density should be checked by such problems as the following:

- If a metal has a density of 7800 kg/m^3 , what would the mass of 500 cm^3 be? Here, there is no need to use the formula: students should simply realize that the density is 7800 g/dm^3 and that the given volume is 0.5 dm^3 .
- What is the volume of 1.3 g of air if its density is 1.3 kg/m^3 ? The answer should be reasonably apparent without the use of a formula technique.

S6.12: Applications of density

Consideration should be given to such topics as the following:

- the range of densities of many substances, such as:

Substance	Density kg/m^3	Substance	Density kg/m^3
hydrogen	0.1	aluminum	2 700
air	1.3	iron	7 860
cork	240	brass	8 500
ice	820	silver	10 500
water	1000	mercury	13 600
milk	1028	gold	19 300

- the changes in density during expansion and contraction;
- the changes in the density of water with changes in temperature;
- the detection of substances by their densities;
- the testing of various liquids, such as milk, blood, battery electrolyte, by means of their densities.



UNIT S7: POPULATIONS AND COMMUNITIES

In this core unit, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic in the unit.

Topics	Number of Periods
S7.1 *The biosphere	1
S7.2 Biomes	14
S7.3 *Ecosystems	
S7.4 *Populations and communities	
S7.5 *Producers, consumers, and decomposers	
S7.6 *Carnivores, herbivores, and decomposers	
S7.7 Mutualism and parasitism	2
S7.8 *Predation	
S7.9 Pyramids of numbers, biomass	
S7.10 Cycling of matter	
S7.11 Succession	2
Review and evaluation	2
	21

Preamble

Ecological relationships involve groups of living organisms. However, every group is made up of individuals that are adapted to live in particular environments. This unit is designed to help students develop an understanding of the abiotic factors that determine the nature of the biotic community. The extensive use of field and classroom investigations, discussions, debates, and projects are recommended to encourage student involvement and an appreciation of our ecosystem.

It may be helpful to refer to Interdependence of Living Things (Unit E4) before beginning this unit.

S7.1: The biosphere

Students should become familiar with the concept of the biosphere, the relatively thin shell around the earth extending only a few kilometres above and below sea level which includes all parts of the water, land, and air inhabited by living things. They could distinguish among the atmosphere, the biosphere, and the lithosphere.

Suggested terminology: *biosphere, atmosphere, lithosphere.*

S7.2: Biomes

A biome is a broad region within a biosphere that encompasses a community of plant and animal life that is typical of a geographic area with one kind of climate. The terrestrial biomes include the temperate deciduous forest, taiga, tundra, grasslands, and the tropical rain forest. The marine biome occupies two-thirds of the earth's surface.

Students might investigate the major plant and animal life in at least two biomes, using those that are most familiar to them. Audio-visual materials such as movies, filmstrips, and film loops may be helpful in presenting this concept. Emphasis should be placed on the influence of climate in determining the type of plant and animal life within a biome. What is climate? What is weather? Is all of the province of Ontario part of the same biome? Students may be provided with data on the physical features and climate of an unidentified biome and asked to describe the type of biotic community that might be expected to exist in the region.

Suggested terminology: *tundra, taiga, biome, biotic community.*



S7.3: Ecosystems

Develop the concept of the ecosystem (ecological system), illustrating its biotic (living) and abiotic (non-living) components. Possible ecosystems for study may include the terrestrial (forest, field, and soil) and the aquatic (marine, fresh-water). Refer to Topic E4.2: Concept of an Ecosystem. Field trips to study forest, field, or pond ecosystems are useful to illustrate the relationships between the biotic and abiotic components of an ecosystem. At least one field investigation should be undertaken to provide students with an opportunity to observe, collect, and record data and to describe the physical and living features of an ecosystem. Questions related to such an investigation could include the following:

Biotic Community (See also Topic S20.5.)

- What plants are present? (shrubs, annual plants, saplings, mature trees)
- What animals are present? (mammals, birds, reptiles, insects)
- What evidence is there that animals live in the area?
- What living organisms are present in the soil?

Abiotic Environment (See also Topic S20.2.)

- Describe the soil: is it wet or dry?
- Does the soil contain much plant matter?
- Is there any evidence of decomposition?
- What climatic factors are present, how are they measured, and what are their effects?

A soil sample may be brought back to the classroom for further study. Refer to Topic E4.3: Types of Communities.

Suggested terminology: *ecosystem, biotic, abiotic*.

S7.4: Populations and communities

Students should be able to distinguish between a population of an organism (perch in a pond) and a community containing several populations of a variety of organisms (fish, daphnia, crayfish, caddis fly larvae). If a forest ecosystem is studied, the number of mature trees, saplings, and shrubs in a given area may be determined. Skill in the measurement, collection, and recording of data should be emphasized. Students could also be asked to determine whether the forest is young, middle-aged, or mature.

Suggested terminology: *population, community*.

S7.5: Producers, consumers, and decomposers

Having studied a typical ecosystem and its community, students should be able to identify relationships and write simple food chains, such as:

grass ► grasshopper ► frog ► snake.

To study food chains, students could write on a sheet of bristol board the names of all plants and animals that were observed in a particular ecosystem.

They could then be asked to identify and connect as many food chains as possible. Who eats whom? What results from the numerous food chains? A discussion could follow on the position in the community that each organism in the food chain or food web holds. Students should consider the role of the human within the plant-animal community. What is each member's role or niche? Students can identify the producers, consumers, and decomposers of the ecosystem that they have investigated. What happens if one or more of the organisms in the food web is removed? How may humans affect the delicate balance of the food web?

Suggested terminology: *decomposer, niche, producer, consumer*.

S7.6: Carnivores, herbivores, and decomposers

By developing examples of complex food webs, students should be able to conceptualize more specific roles or niches. They can identify herbivores, first-order carnivores, second-order carnivores, and top-order carnivores. What niche does man hold? Can an organism occupy more than one niche? The need for decomposers in the cycling of matter should be developed.

Suggested terminology: *omnivore, herbivore, carnivore*.

S7.7: Mutualism and parasitism

A discussion of the relationships arising from the study of food chains and food webs should enable students to recognize and understand the concepts of mutualism and parasitism.

Suggested terminology: *mutualism, parasitism*.

S7.8: Predation

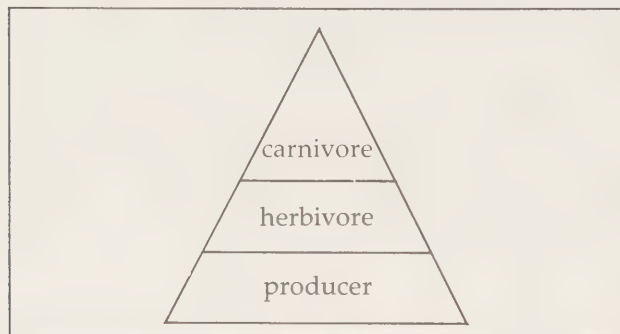
Students should be able to cite a number of examples of predation in nature.

Are humans always part of a food web? Are humans predators? Students may wish to consider possible examples, if any, of predation, mutualism, and parasitism within a mutually exclusive human community and discuss the effect of moral values on such interrelationships.

Suggested terminology: *predation*.

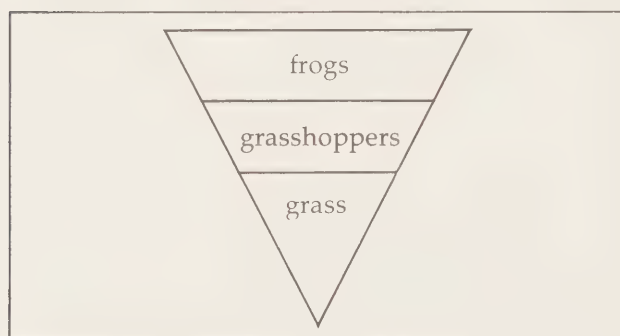
S7.9: Pyramids of numbers, biomass

Using examples that are familiar to students, the teacher may develop the model of the pyramid of numbers. What does this pyramid (illustrated here) tell us about food relationships?



Students could predict where humans fit into the pyramid of numbers. It may be feasible to further develop the students' understanding of trophic levels by describing pyramids of biomass and energy and by illustrating the energy flow from one member of a food chain to another. Students may also consider the consequences of an inverted pyramid such as that illustrated here.

Suggested terminology: *biomass*.



S7.10: Cycling of matter

Several cycles (such as carbon dioxide, water, and nitrogen) may be considered in discussing the cycling of matter. The carbon dioxide and oxygen cycles could be studied as one cycle, thus emphasizing the interrelationship between photosynthesis and respiration. Reference should be made to Topic E4.5: Photosynthesis and Respiration. Word equations for photosynthesis and respiration could be incorporated in this study. Some further questions for discussion might include the following:

- What is the role of the producer, the consumer, and the decomposer in the cycling of matter?
- Why is it necessary for matter to be recycled?
- What is the source of the substances that make up the body of an organism?
- What would happen to the carbon dioxide-oxygen cycle if all the producers were to disappear?
- What would happen to the nitrogen cycle and, thus, to the plant and animal community if all the decomposers were to disappear? For example, how would potting soil that has been sterilized affect a house plant?

S7.11: Succession

The interdependence of plants and animals on each other and on their environment should be illustrated by observing the changes that occur during both primary and secondary succession. The successive stages from bare rock may include lichens, mosses, grasses and ferns, shrubs, grey birch and poplar, maples and beech. Succession on a small scale may also be observed by setting up a straw infusion in the bottom of a glass container. Daily or periodic microscopic observation will illustrate a progressive accumulation and transition of protozoa from one species to another.

Suggested terminology: *succession*.

UNIT S8: STRUCTURE OF MATTER

In this core unit, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic in the unit.

Topics	Number of Periods
S8.1 *Some processes of science	1
S8.2 *The particle theory	5
S8.3 *The atomic theory	2
S8.4 Ions and conductivity	2
S8.5 *The elements	1
S8.6 Classification	2
S8.7 The periodic table	2
S8.8 *Elements and compounds	1
Review and evaluation	2
	18

Preamble

The focus of this unit is on the development of the intellectual skills of scientific inquiry. Such skills are required components of the Intermediate Division science program. Some of the processes that will play a role in this unit are identifying a problem, developing a hypothesis, designing an experiment, organizing and processing data, evaluating the hypothesis, inferring relationships, formulating generalizations, and formulating theories and models.

To develop their abilities in these areas, students will study the particle theory of matter and the development of the atomic theory.

It is important for students to develop the appropriate skills from an experimental basis, if possible. Where this is not possible, for example, in developing the atomic theory, students should appreciate the inquiry skills that were utilized in the development of the theory. This unit permits students opportunities to organize, process, and interpret data, particularly during consideration of Topics S8.6: Classification and S8.7: The Periodic Table.

It is expected that students will question the evidence upon which various theories are based, and this may lead naturally to the study of other units. It is hoped that students will become interested in the concept of chemical change and in the formation of a variety of chemical compounds.

S8.1: Some processes of science

As indicated in the preamble to this unit, there are a number of inquiry skills or processes listed with which students should become familiar during the study of this unit. Initially, teachers may wish to introduce students to these (and, perhaps, to some other processes) and to illustrate them with examples. However, teachers may prefer to introduce these processes as the stages are encountered during the development of the particle theory.

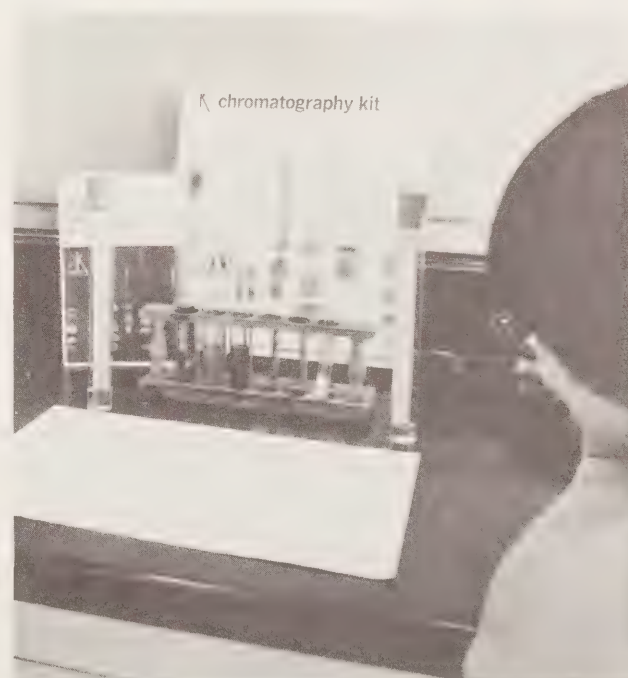
Students should realize that scientific theories and models are dynamic and must allow for change based on new evidence.

Suggested terminology: *inquiry skills, intellectual processes, hypothesis, generalization.*

S8.2: The particle theory

The particle theory states that matter is made up of tiny invisible particles which are in motion. Obviously, when one picks up a piece of steel, this idea seems ridiculous. Clearly, the steel is one solid slab of matter. A number of experimental investigations should be undertaken by the student, leading to the description of matter as particulate. For example, students might consider the circumstantial evidence developed by a study of some of the following:

- Brownian motion
- crystal formation
- the nature of thin films
- chromatographic separation
- the decomposition of a metal oxide
- the displacement by iron of the copper in blues-tone
- the reaction of sodium bicarbonate and vinegar to produce carbon dioxide
- the nature of drops



An estimate of the thickness of a film of soap leads to the conclusion that the particles in the soap must be extremely “thin”. (See Topic S6.5: Length, Area, and Volume.) When looking through a microscope at a drop of milk, students will see large particles in constant motion. This leads to the possible conclusion that small, invisible particles might be pushing the larger particles around.

Throughout the investigations students should be reminded of the processes of scientific inquiry.

Suggested terminology: *theory, particle theory, circumstantial evidence.*

S8.3: The atomic theory

Although consideration of this topic does not readily allow for experimental consideration, the historical development of this theory will show the dynamic features of theory construction. In this regard, students should be exposed to the theories of Democritus, Dalton, Thompson, and Rutherford. Students should be able to indicate the location of electrons, protons, and neutrons by means of a simple diagram of an atom.

Suggested terminology: *electron, proton, neutron, atom.*

S8.4: Ions and conductivity

The following solutions might be tested for electrical conductivity: sodium chloride, potassium iodide, calcium chloride, copper sulphate. Students should relate the positive test for conductivity to the presence of ions in the solution. They should be able to demonstrate that they understand how a neutral atom becomes an ion by the gain or loss of electrons.

Suggested terminology: *ion, conductivity, neutral atom.*

S8.5: The elements

Students should be able to define an “element” as matter containing only one kind of atom. A more thorough definition accounting for the existence of isotopes can be derived in more advanced science programs. Since the names and symbols of the elements are commonly used in science courses, students should know those that are most common: for instance, hydrogen (H), helium (He), carbon (C), nitrogen (N), oxygen (O), neon (Ne), sodium (Na), aluminum (Al), chlorine (Cl), potassium (K), calcium (Ca), iron (Fe), copper (Cu), iodine (I), uranium (U).

Suggested terminology: *element, name, symbol.*

S8.6: Classification

This topic gives students the opportunity to refine the observational skills developed during Properties of Matter (Unit E.6). The teacher should provide the students with samples of elements, or pictures and descriptions of elements. Students should be able to classify the elements according to some of their physical properties and also according to electron transfer. This may lead to an empirical definition of the terms “metal” and “non-metal”.

S8.7: The periodic table

The periodic table serves as a means of organizing the elements. Students should not be required to memorize features of the table; however, they should understand that elements are grouped according to similar characteristics. A discussion of a particular family may be undertaken to illustrate the periodic trend in properties.

The following is a demonstration experiment that might be used to illustrate the periodic trend in properties: Two elements, lithium and sodium, are shown to the students, who are told that they are members of one family. Another member of this family is “missing” – actually it has got into another group of elements – such as magnesium, calcium, carbon, potassium, and sulphur. This second group is shown to the students. The problem is to find the element in the second group that belongs to the lithium-sodium family. All seven elements are then observed as they are allowed to react with water, and potassium should be selected as the “missing” family member. From this simplistic demonstration, similarities in properties of elements within some families may be developed. Given two elements in one family, students may make fairly good predictions about the properties of a third member.

CAUTION: Sodium and potassium react vigorously with water, giving off hydrogen. The demonstration containers should be covered during the reaction to avoid splattering. Only small pieces of each element should be used in the demonstration. After each reaction, hydrogen should be allowed to escape to prevent the possibility of an explosion. Goggles should be used to protect eyes.

Suggested terminology: *periodic table.*

S8.8: Elements and compounds

Students should be able to differentiate between a compound (a pure substance made up of at least two simpler substances) and an element (a pure substance made up of only one kind of atom). Thus, a compound can be decomposed into simpler substances by ordinary chemical means while an element cannot. Since hydrogen peroxide (H_2O_2) will decompose in the presence of manganese dioxide to produce water and oxygen, this shows that hydrogen peroxide is a compound.

Suggested terminology: *chemical compound.*

UNIT S9: CONSUMER CHEMISTRY

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Note: The following is a set of sample topics for this unit.

Topics	Number of Periods
S9.1 *Soap and a related problem	2
S9.2 *The best cleanser? Developing a hypothesis	2
S9.3 *Designing an experiment on cleansing	2
S9.4 *Data on soap as a cleanser	4
S9.5 *Interpreting the data on soap	4
S9.6 *Evaluating the "cleanser hypothesis"	2
S9.7 Generalizations regarding the cleanser	2
S9.8 Explaining the soap problem	2
Review and evaluation	2
	22

Preamble

This unit deals with the application of the processes of science to consumer chemistry. The factual content of this unit should not be treated as the primary focus. The key issue is to have students develop an awareness of the various processes involved in a scientific investigation, in this case the processes applied to consumer chemistry.

One illustrative problem is used in this unit as an example, that of the cleansing ability of various brands of soap. However, any other consumer-related issue may be considered within the general spectrum of consumer chemistry. Other issues that might be suitable are the efficiency of various detergents, the buffering action of different antacids, the durability of certain cosmetics, the effectiveness of a variety of dyes, the dissolving power of a selection of solvents, the hardness of some samples of water, the acidity and alkalinity of different types of soil, or any other appropriate investigation that may be of interest to the students.

The topic of investigation should be one that will suitably illustrate the following processes of inquiry:

- identifying a problem;
- developing a hypothesis;
- designing an experiment or test;
- organizing and processing data;
- interpreting data;
- evaluating a hypothesis;
- formulating a generalization;
- creating a theory or model.

The first six of these processes are considered mandatory components for this unit of study, while the last two are recommended, but may be omitted by some students.

The topic headings for this unit are related to the example, the cleansing ability of soap. However, while the topics must involve the processes listed above, they may be applied to any similar investigation, provided that it is related to consumer chemistry.

S9.1: Soap and a related problem

Students can first be encouraged to list a number of problems concerned with consumer chemistry. This will probably cover a wide range of issues from broad areas to specific points. An example of a broad area would be: Are some brands of soap better than all others? Such a general problem can be pursued if time permits, but it is recommended that the students be encouraged to focus their attention on a related problem that is more specific. For example, is there any difference in the cleansing abilities of several commercial brands of soap, labelled brands A, B, C, and D?

Suggested terminology: *problem identification.*

S9.2: The best cleanser? Developing a hypothesis

In stating a specific problem, students should be directed to postulate a hypothesis in such a manner that it can be investigated. Thus, parameters are introduced for the student investigation. A hypothesis is formed in an attempt to tentatively answer the problem in operational terms. For example, a student notes that brand B seems to have the most pungent odour and, therefore, proposes the following hypothesis: Brand B has the greatest cleansing ability in removing oil from denim (a pair of oily jeans) and brands A, C, and D have equal ability.

Suggested terminology: *hypothesis formation, postulate.*



S9.3: Designing an experiment on cleansing

Having formed their hypotheses, students are then faced with the problem of designing related experiments to test them. Consideration must be given to required materials and suitable techniques. An experiment or test must be valid. In the case of the four brands of soap, students must determine which factors are variable and which are to be kept constant. Clearly, the only variable, at least as a starting point, is the brand of soap used. However, students must be conscious of such factors as the size of the containers, the method of mixing soap and water, the temperature of the water, the mass or volume of the soap and water, the amount of shaking or stirring, the uniformity of the material to be cleansed, and how the relative amount of cleansing is to be rated. The experimental design should include the concept of verifying the data. This verification should be both internal and external: internal in that the experimenter does the test several times to compile reliable data, with averages where applicable; and external in that fellow students carry out separate tests so that independent data are compiled. Students should suggest reasons for the need to have repeated tests, averages, and internal and external testing.

Suggested terminology: *experimental design*.

S9.4: Data on soap as a cleanser

Once a sufficient amount of data is accumulated on the soap investigation, the students could then be asked what they should do with the data: how the data should be organized; and how they should be presented in a form for others to examine. This raises several possibilities: the data may be presented in a series of statements, a well-organized table, a graph or series of graphs, or perhaps a classification scheme. Students should be able to consider a variety of ways of organizing, processing, and presenting data.

Suggested terminology: *data organization*.

S9.5: Interpreting the data on soap

Students should now determine the pattern or meaning that is inherent in the data that have been collected and processed. The initial stage of interpretation is usually operational, that is, the data are expressed in terms of what happened in the particular experiment or test. For instance: Brand B is the best cleanser of motor oil from denim, followed in order by brands C, D, and A. Questions such as the following may then be considered:

- Would the test produce different results in hot water than in cold?
- Would the cleansing abilities be affected by different concentrations of the brands in water?
- Would the results be different if oily denim were replaced by ink-stained silk?

Suggested terminology: *data interpretation*.

S9.6: Evaluating the “cleanser hypothesis”

Is the interpretation of the data consistent with the hypothesis? In the example, the interpretation of the data is found to disprove the hypothesis. This does not mean that the hypothesis was without value. A new hypothesis may be formed because the first one proved to be incorrect. For example, after observing that brand B is more transparent than brands A, C, and D, students may postulate that the more transparent a soap is, the better is its cleansing ability. This could then be tested and a new hypothesis formed leading to more and more data and resulting knowledge. Students should realize that the evaluation, revision, or renewal of a hypothesis is a distinct and important stage in the inquiry process.

Suggested terminology: *hypothesis evaluation*.

S9.7: Generalizations regarding the cleanser

One possible generalization is that brand B is always a better cleanser than brands A, C, or D. Often this kind of generalization is made without sufficient evidence. Students may propose a number of tests that will have to be conducted before they will accept this generalization. They may suggest modifications of this generalization which they would be prepared to accept. Perhaps different groups of students could carry out a variety of experiments in order to find more evidence to support or refute a stated generalization.

Suggested terminology: *generalization*.

S9.8: Explaining the soap problem

Theories or models are products of inquiry formulated by the process of inferring. They provide explanations of observations or generalizations in terms of some analogy or argument based on previously gained experience or knowledge. For example, students may theorize that soap brand B is the best cleanser because it is the most alkaline or because it produces more suds than the other brands. The validity of such theoretical explanations may then be discussed with reference to their applicability to all known kinds of soap. It should be obvious then that predictability becomes an important factor in evaluating a theory or model. If a new set of brands of soap is tested, the most alkaline or the one having the most suds, depending on the proposed theory, should then be the best cleanser.

Theories or models may be invented to provide further explanation of the observed phenomenon. Here, for example, an alkali may be pictured as a miniature gremlin that breaks up oil particles into soluble entities, or soap bubbles may be seen as swallowing oil particles that normally would cling to cloth. The role of a theory or model in helping to visualize or explain a phenomenon should be stressed.

Suggested terminology: *theory, model.*



UNIT S10: CONTINUITY

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
S10.1 Reproduction in plants and animals	3
S10.2 *The need for meiosis	1
S10.3 *DNA and the genetic code	2
S10.4 Embryology	1
S10.5 The human reproductive system	1
S10.6 *Human genetics	2
S10.7 *Mendelian genetics	3
S10.8 *Chromosome theory	3
Review and evaluation	2
	18

Preamble

“Continuity” may be defined as “an unbroken sequence of events in time”. Biologically, one can refer to the continuity of genetic content from the reproductive cells of the parents to the offspring, as well as the continuity of traits and characteristics from one generation to another. The first five topics in this unit deal with reproduction and the last three topics with heredity. This unit provides an opportunity for students to relate the reproductive process to heredity and, in particular, to their own inheritance. Student background in mitosis (see Unit S1: Cells and Their Processes) and reproduction (see Unit E11: Life Cycles) may be considered necessary prerequisites for this unit.

S10.1: Reproduction in plants and animals

Reference should be made to Life Cycles (Unit E11) for suggestions regarding the presentation of material on reproductive methods in plants and animals.

Using a variety of materials such as audio-visual material and slides of reproductive structures and such live specimens as conjugating paramecia, the teacher can provide students with observable examples of a variety of reproductive methods. A treatment of reproductive methods might include examples of fission, budding, spore formation, vegetative reproduction, conjugation, pollination, and fertilization. Students can distinguish between sexual and asexual reproduction and can determine the advantages to each organism of its method of reproduction. For example, asexual methods of reproduction ensure that offspring are identical to the parent. In this way, there is complete continuity. Sexual reproduction provides a mechanism for change and variation within the species. This enables the species to adapt and survive, and results in continuity within the species.

Suggested terminology: *fission, spore, budding, conjugation, gamete, egg cell, sperm cell, fertilization, vegetative reproduction, pollination, asexual reproduction, sexual reproduction.*

S10.2: The need for meiosis

A comparison of asexual and sexual reproduction can be used to enable students to understand the concept that among the higher plants and animals an egg and a sperm each contain half the genetic content of the species. It may be necessary to review mitosis (see Topic S1.5). Students should be familiar with the description of genetic content (chromosome number) as “2N” (diploid) and “N” (haploid).

Commercially prepared slides and wet mounts of the alga *spirogyra* may be used to further illustrate meiosis within the context of alternation of generations.

Reference may be made to Life Cycles (Unit E11) to consolidate this topic.

Suggested terminology: *meiosis, haploid, diploid, N, 2N, chromosome, alternation of generations.*

S10.3: DNA and the genetic code

Students should become familiar with a model of DNA (deoxyribonucleic acid), a model that illustrates its components and their helical arrangement. It is important to emphasize that it is the passage of chromosomes from parent to offspring that ensures continuity of traits or characteristics from one generation to another, and that DNA is the molecule within the chromosome structure that determines the traits of the organism.

Teachers may wish to avoid a discussion of the molecular make-up of DNA in terms of its component bases and deoxyribose, unless the students' interests and abilities suggest a need for additional information.

Suggested terminology: *DNA, trait, nucleic acid.*

S10.4: Embryology

Continuity may be further illustrated by the sequence of events in the development of the zygote into an individual organism.

Prepared slides of cleavage in starfish may be used to illustrate the formation of specialized tissues which eventually form the structures of the organism.

It is advisable to avoid a detailed study of embryology. The concept of continuity of development should be emphasized rather than the specialized stages of the developing embryo.

Suggested terminology: *tissue, development, embryology.*

S10.5: The human reproductive system

The human reproductive system may be used to show how reproductive organs are designed to ensure continuity of the species. The advantages of internal fertilization, embryonic and foetal development within the uterus, the placenta, menstrual controls, and lactation should be briefly discussed. Any detailed discussion of anatomic structure should be avoided.

Suggested terminology: *menstrual control, placenta, foetus, lactation.*

S10.6: Human genetics

Since most students are interested in their own heredity, students could list examples of traits that they have inherited. Such traits might include tongue-rolling, tasting of PTC (phenylthiocarbamide), and ear-lobe attachment. Students may then hypothesize on the patterns of inheritance for these traits. They might also suggest explanations of the mechanisms of such inheritance.



S10.7: Mendelian genetics

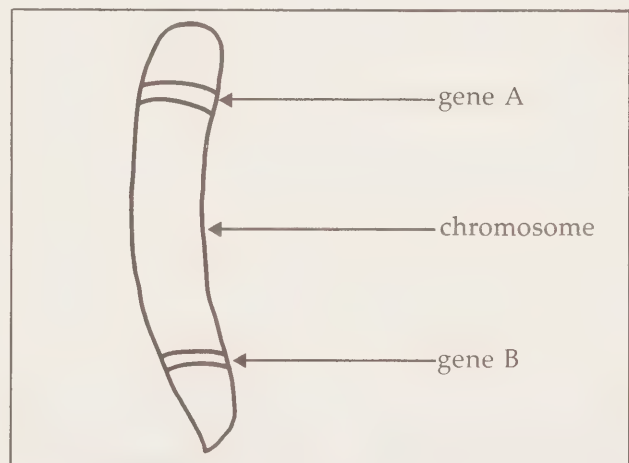
Through an examination of several traits, such as tongue-rolling, tasting of PTC, and ear-lobe attachment, the principles of Mendelian genetics may be introduced. The law of segregation and the law of independent assortment should be discussed. The need for the use of Punnett squares should be developed in this topic.

If materials are available, experiments with drosophila and tomato seedlings may be attempted to show the following Mendelian phenotypic ratios: 3:1, 1:2:1, 9:3:3:1.

Suggested terminology: *Punnet square, homozygous, heterozygous, dominant, recessive, ratio, phenotype, genotype, hybrid.*

S10.8: Chromosome theory

The concept of a gene as a determiner of a genetic characteristic or trait is to be introduced in this topic. Students may design a model of a chromosome showing several component genes. A "gene" may be defined as "that portion of the chromosome that carries the code (DNA) for the production of a trait, such as blue eyes".



Students may hypothesize as to what happens when a blue-eyed person and a brown-eyed person have children.

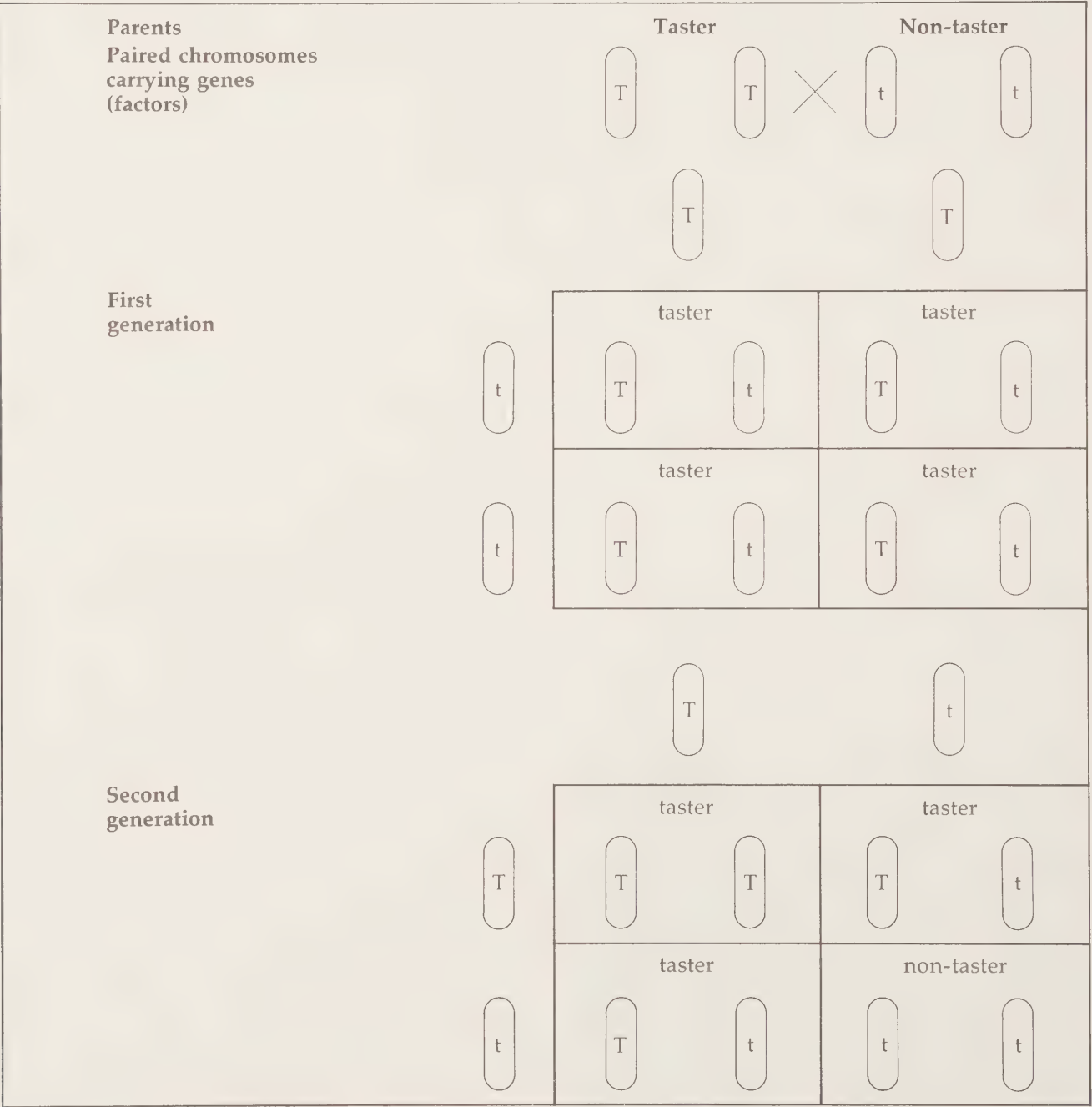
Students should understand the following concepts:

- Chromosomes and genes occur in pairs in the zygote and in all body cells.
- Chromosomes and genes segregate during meiosis, and only one member of each pair of chromosomes normally enters a zygote.
- Chromosomes segregate independently of one another.

To show that chromosomes and genes segregate in a similar pattern, a Punnett square, which shows both chromosomes and genotypes, may be helpful. For example, a PTC tasting could be used:

A good understanding of these principles may be developed by providing students with various genetics problems involving at least two factors (dihybrid crosses) and completely dominant characteristics.

Suggested terminology: *segregate, independent assortment, gene, chromosome, monohybrid cross, dihybrid cross.*



UNIT S11: ELECTRICITY AND MAGNETISM

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
S11.1 Electrostatics	1
S11.2 *Induction	2
S11.3 Shielding and discharging	1
S11.4 Electrochemical cells	2
S11.5 Electric units	3
S11.6 *Electric energy	2
S11.7 *Electric circuits	3
S11.8 *Magnetism	2
S11.9 *Electromagnetism	2
S11.10 Electric energy conversions	1
Review and evaluation	2
	21

Preamble

This unit is a continuation of Magnetism and Electricity (Unit E13), which may have been taught in Grade 7 or 8. Therefore, the teacher should blend the previous work with the new work. The majority of the review material in this unit can be integrated with the pertinent topics as the need arises; for those students who have not taken the elementary unit in this area, the material can be expanded slightly in order to provide a logical treatment of the subject well within their grasp. This unit should be taught after Measurement (Unit S6), if possible.

Electricity and magnetism are both forms of energy and are related to each other in that each can produce the other. In fact, they exist together in motors and generators, all electric circuits, and all forms of electromagnetic radiation including X-rays, visible light, and radio waves. The importance of electromagnetic phenomena is staggering to the imagination: our lives are dependent on this form of energy.

Electricity has become essential to our affluent way of life. Students might consider life without electricity for a week. All electric appliances would be useless; thermostatically controlled services would cease; candlelight and fireplaces would have to offer their cheer as cold sandwiches were munched in front of a blank TV.

This unit should assist students in gaining a deeper understanding of some of the essentials related to electricity and magnetism. Students will learn new laws and rules, will use electric and magnetic devices, will search to solve some scientific mysteries, will apply theoretical reasoning to formulate explanations, and will, it is hoped, learn to use electrical energy wisely.

S11.1: Electrostatics

Students should review the production of positive and negative charges, the law governing the attraction and repulsion of unlike and like charges, and simple theoretical explanations based on electrons and protons.

Suggested terminology: *electrostatics, like and unlike charges, positive and negative charges, electrons, protons.*

S11.2: Induction

The structure and use of a metal-leaf electroscope should be reviewed. The pith-ball electroscope may also be introduced if desired. The meanings of “conductor” and “insulator” should be reviewed as well.

Charging by inductance should be demonstrated through the use of two conductors on insulated stands. Students should be able to deduce which conductor is positive and which is negative and to explain the results by means of the electron theory.

Students should be able to charge a single conductor, such as the knob of a metal-leaf electroscope, by induction and to explain the process by means of the electron theory.

Suggested terminology: *conductor, insulator, inductance, induced charge, grounding.*



S11.3: Shielding and discharging

Examples of some of the applications of electrostatics should be introduced through student activities or demonstrations. For example, (a) students should be able to perform a simple activity showing electrostatic shielding, such as shielding an electroscope; (b) the teacher may demonstrate electrostatic discharging from spheres and points that are charged by a Wimshurst machine or a Van de Graaf generator.

The use of electrostatic shielding devices and lightning rods should be explained.

Suggested terminology: *shielding, electrostatic generator, discharge, lightning conductor.*

S11.4: Electrochemical cells

Students have observed evidence of the flow of electric charges. What are the conditions necessary to maintain a flow of charges? One is a closed circuit and the other is a steady supply of charges. Students should make a simple voltaic cell and observe electric energy production from chemical energy. Some students may recall the “electric lemon” to which reference is made in Magnetism and Electricity (Unit E13). The actual chemical reactions need not be known in detail, although a simple explanation of the electric action in a voltaic cell in terms of anions and cations could be given.

The dry-cell and storage battery should be treated as applications of electrochemical activity with emphasis on the rechargeable feature of certain cells.

Suggested terminology: *anode, cathode, anion, cation, voltaic cell, dry cell, primary and secondary cells, rechargeable.*

S11.5: Electric units

This topic deals with electric units of measure, namely, the coulomb, ampere, volt, ohm, joule, and watt.

A theoretical model may be helpful to explain units. “Gremlins” could carry “buckets” of electrons across a cell and exert energy in doing so against forces of repulsion. Within the circuit, certain amounts of energy per “bucket” are involved in transferring charges from one point to another.

Students can understand that it is the electrons that flow in a circuit. A “bucket” or coulomb (C) is just a group of electrons – a very large group. As water flows in litres per second, so electrons flow in coulombs per second (C/s) or amperes (A).

The “gremlins” move electrons and do a certain amount of work per “bucket” measured in joules (J) per coulomb (C); this ratio is called the potential difference and is expressed in volts (V). The voltage of a cell is generated from chemical energy; the electrons then transfer energy in joules per coulomb across various parts of the circuit. The parts are said to have a potential difference of so many joules per coulomb (J/C) or, simply, so many volts (V).

The opposition or resistance to the motion of electrons is measured in ohms (Ω). The definition of resistance may not easily be explained in terms of “buckets” and “gremlins” but perhaps somewhat as follows. In comparison to a low resistor, a high resistor requires high voltage (that is, plenty of energy per charge) for a certain flow of current. Thus, resistance and voltage are proportional to each other. On the other hand, if the voltage or energy per charge is constant, a high current implies low resistance and vice versa. Thus, the resistance and amperage are inversely proportional, and it is natural to define the ohm (Ω) as a volt per ampere (V/A). (Incidentally, this is not Ohm’s law.)

Power is the rate at which energy is transferred in joules per second (J/s) or watts (W).

The following formulas should be known by some students:

$$I = Q/t \quad (1 \text{ ampere} = 1 \text{ coulomb per second})$$

$$V = E/Q \quad (1 \text{ volt} = 1 \text{ joule per coulomb})$$

$$R = V/I \quad (1 \text{ ohm} = 1 \text{ volt per ampere})$$

$$P = E/t \quad (1 \text{ watt} = 1 \text{ joule per second})$$

where I denotes the current in amperes (A),

Q the charge in coulombs (C),

t the time in seconds (s),

E the energy in joules (J),

V the potential difference in volts (V),

R the resistance in ohms (Ω)

and P the power in watts (W).

Some students may be interested in electric work and could solve simple problems involving the above formulas.

Suggested terminology: *coulomb, ampere, volt, ohm, joule, watt, electric current, potential difference, resistance, energy, power.*

S11.6: Electric energy

Due to the energy crisis it is important for students to realize that electric energy should be carefully measured, that it can be used wisely or foolishly wasted, and that it costs money.

Students should know that a watt second is equivalent to a joule of energy. A 60 W bulb left on for half an hour or 1800 s uses $60 \text{ W} \times 1800 \text{ s}$ or 108 000 W•s or 108 000 J of energy. This would normally be expressed as 108 kJ. Students should realize that we are fortunate in Canada because electric energy is comparatively inexpensive. However, wastage soon amounts to immense quantities

if people are indifferent. If each Canadian of Intermediate Division age or older left a 60 W bulb on needlessly for half an hour per day, in a single month we would have wasted about one and a half million million joules of energy in that month.

As Canada gradually adopts SI units, we will one day pay for electric energy at a rate of so many cents per megajoule (¢/MJ). A few problems based on this principle should be given to students. Presently, we are charged by the kilowatt hour, the amount of energy used at a rate of 1000 W for an hour. A 1000 W iron that is used for an hour expends 1 kW•h of energy. Related problems should be solved.

Suggested terminology: watt second, joule, megajoule, kilowatt hour.

S11.7: Electric circuits

The correct use of the voltmeter and ammeter should be explained. Students should then set up a simple series circuit and measure the total current, the current through each component, the total potential difference, and the potential difference of each component. The same can be done for a parallel circuit. The basic electric characteristics of a series and of a parallel circuit can then be summarized.

The danger and prevention of short circuits should be illustrated and discussed.

Suggested terminology: voltmeter, ammeter, parallel circuit, series circuit, short circuit, fuse.

S11.8: Magnetism

The teacher should review or briefly introduce how a magnet may be made, the law of attraction and repulsion, magnetic forces and fields, and the molecular theory of magnetism. Much of this will have been taken by those students who have had Magnetism and Electricity (Unit E13).

Suggested terminology: magnetic pole, north pole, south pole, attraction and repulsion, magnetic force, magnetic field, molecule.

S11.9: Electromagnetism

Students should “discover” the magnetic field about a wire that is conducting an electric current. They should find the direction of the magnetic lines of force and establish the “left-hand rule”.

By means of an experiment, students should find the polarity of a helix and establish the “helix rule”. Practical uses of electromagnets can be mentioned; these include the electric bell, the magnetic lift, the circuit breaker, and the galvanometer.

Suggested terminology: left-hand rule, helix rule, polarity, electromagnet.



S11.10: Electric energy conversions

A session on transformations of electric energy should be useful. First, a list could be made of examples of various kinds of energy that can be converted to electricity: chemical, mechanical, magnetic, solar or light, and thermal. Second, a list could be made of examples of various kinds of energy into which electric energy can be converted: light, heat, sound, mechanical, and magnetic. Where feasible, actual demonstrations of such transformations would enrich this topic.

UNIT S12: ENVIRONMENTAL CHEMISTRY

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
S12.1 *The energy crisis	4
S12.2 Future energy sources	4
S12.3 *Air pollution	4
S12.4 *Water pollution	8
Review and evaluation	2
	22

Preamble

The intent of this unit is to permit students to develop the ability to analyse the chemical environmental information to which they are exposed. It is important that teachers be concerned with the impressions that are made on students at this age.

Students should be made aware of the role of chemistry in causing and in solving environmental problems. Students should be able to list some of the contributions made by chemistry to our life style. At the same time, they should be able to associate such contributions with possible environmental problems.

A judicious selection of resource material should provide the teacher with a very powerful and exciting unit of study. Use may also be made of the excellent simulation games and role-playing strategies that are available. The development of material on energy sources and the study of air and water pollutants is left to the teacher. Local resources and current issues should dictate the approach taken.

S12.1: The energy crisis

During the early 1970s the title of this topic would most certainly have been followed by a question mark. This no longer is the case. Every student is aware of such terms as "energy conservation" and "energy crisis". During the study of this topic, students can compile a list of energy sources and indicate the uses for each source listed. They can explain why developing nations have different energy requirements than have developed nations. If time permits, they can examine and discuss the data relating to Canada's known energy reserves and future requirements. Existing methods of energy conservation can be explored. Students should recognize the limitations of hydro-electric power and the reasons for the introduction of steam-driven electric power plants.

Students should be able to suggest possible ways and means of minimizing thermal pollution. With regard to thermal pollution, students can be given the opportunity to determine experimentally the effect of temperature on gas solubility. Bottles of soda water at varying temperatures can be used in such an investigation. It would be useful to relate the problems of thermal pollution to the decreased concentration of oxygen in the water surrounding a steam-generating plant.

It is important for students to realize that there are many decisions that must be made in determining the wise use of different fuel sources. Some of these decisions are based on chemical technology, but most are based on economic, political, and social pressures, and many are related ultimately to the question of survival.

Suggested terminology: *thermal pollution*.

S12.2: Future energy sources

Many energy sources are receiving publicity today. Students could be asked to describe and discuss the merits of the following alternative energy sources: (a) geothermal energy, (b) solar energy, (c) nuclear energy, (d) hydrogen, (e) wind and tidal energy. Students should be aware of some of the inherent technical and chemical problems associated with each of these alternative sources.

Some simple terminology could be introduced in this topic. For example, students could be exposed to the basic concepts of nuclear fission and fusion.

Illustrative experiments could be done to illustrate some energy sources. For example, the power of solar energy can be illustrated by means of a hand magnifying lens, which can focus solar energy to heat water or to burn paper.

The problems of distributing hydrogen as an energy source could be illustrated by studying the reaction of hydrogen and oxygen. It is important that students realize that safety problems are associated with the distribution and use of hydrogen as a fuel.

Suggested terminology: *geothermal, fission, fusion*.

S12.3: Air pollution

What are the sources of common air pollutants? How are these pollutants monitored? What methods have proved effective in reducing the levels of such pollutants? These and other questions could lead to the investigation of a particular air-pollutant problem. A study of sulphur dioxide could be undertaken to illustrate the effects of a common air pollutant. Students could be allowed to carefully prepare sulphurous acid (H_2SO_3) from sulphur dioxide (SO_2) by burning sulphur (S) in air and dissolving the product in water (H_2O).

CAUTION: Students should perform this investigation under a fume hood. Inhalation of sulphur dioxide gas is to be avoided.

Students could test the acidity of this solution (litmus test) and then test for the bleaching property of sulphurous acid on organic materials such as orange peel and fabrics. Students could write the chemical equations for the production of sulphurous acid (H_2SO_3). They could also observe the local effects of sulphur-dioxide pollution on vegetation and architecture.

As a result of this study students should be aware of the responsibilities of both industry and the individual in combatting air pollution.

Suggested terminology: *sulphur dioxide, sulphurous acid, pollutant.*

S12.4: Water pollution

The measurement of the concentration of oxygen gas dissolved in water is an important test in the study of water pollution. Without a sufficiently high content of dissolved oxygen, aquatic life cannot exist. Bacteria consume oxygen in the presence of organic materials. Students could suggest some other factors that might alter the concentration of the dissolved oxygen.

Students could determine the dissolved oxygen concentration in the water of a classroom aeration tank. This involves the following series of chemical reactions. Manganese (II) sulphate and alkaline-iodide solutions, when added to a water sample, cause a quantity of iodine to be released that is equivalent to the amount of dissolved oxygen present in the water sample. The amount of iodine present can be determined in reaction with sodium thiosulphate, using starch as an indicator. Students could investigate the following questions: Does the temperature of water affect the amount of dissolved oxygen available? Do algae contribute significantly to the oxygen content of lakes and rivers? Other water-analysis tests could be conducted to determine the presence of nitrites, sewage contamination, phosphates, and suspended solids. In all such procedures, it is suggested that students learn to interpret the results obtained. It is to be hoped that, as a result of such understanding, they will develop a better awareness of their environmental responsibilities as citizens.

Suggested terminology: *alkaline, indicator.*



UNIT S13: FUNGI AND SIMPLE PLANTS

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
S13.1 *Characteristics of fungi	1
S13.2 *Bread mould	2
S13.3 Yeast	2
S13.4 Mushrooms	2
S13.5 Parasitic fungi	2
S13.6 *Lichens	2
S13.7 *Complex algae	3
S13.8 *Mosses	3
S13.9 *Ferns	3
Review and evaluation	2
	22

Preamble

In this unit, students will extend their understanding of the diversity among living organisms. This unit complements Viruses, Monerans, and Protists (Unit S22) in building on Classification of Living Things (Unit E2), Life Cycles (Unit E11), and Plants (Unit E15).

Students should recall the work done in Characteristics of Living Things (Unit E1) and should contrast the ways in which fungi, plants, and animals meet their own needs for survival. The study of fungi will introduce the idea that different cells exist to perform different functions and will deal with the method of nutrition by which foods are digested externally by secretion and nutrients absorbed by diffusion.

This unit provides opportunities for students to develop their manipulative skills through growing cultures, preparing microscope slides, using the microscope, and drawing sketches of what they see. There are also opportunities for controlled laboratory experiments, such as investigating the conditions that favour the growth of moulds and yeasts.

S13.1: Characteristics of fungi

Students should be able to list fungal characteristics after viewing several representative plants. Fungi could be compared to algae. Students should understand the meaning of the terms “saprophyte” and “parasite” and be able to use them correctly in discussing fungi. The teacher should help students understand that fungi are classified according to their spore-producing structures.

Suggested terminology: *fungi, spore, saprophyte, parasite.*

S13.2: Bread mould

Students should investigate the structure of bread mould and the conditions for its growth. Through microscopic study, they can identify hyphae, mycelia, rhizoids, stolon, sporangia, and spores. A general understanding of the life cycle of bread mould is considered important. Students should understand and appreciate the importance of moulds. Some time could be allocated to personal research and discussion.

Suggested terminology: *hypha, mycelium, rhizoid, stolon, sporangium, spore, mould.*

S13.3: Yeast

Students should set up a yeast culture and study the structure of a yeast cell and the conditions for its growth. Methylene blue or iodine stain can be added to a drop of yeast culture to observe the structure of the cell under the high power of a microscope. The life cycle of yeast should be briefly discussed so that students understand the significance of yeasts, especially in the process of fermentation and in the making of bread. Students can make drawings to show the general appearance of several yeast cells. They can also make an estimate of the number of yeast cells in the field under high power. How do yeast cells change in structure during the process of fermentation?

Suggested terminology: *yeast, fermentation.*

S13.4: Mushrooms

Students can examine the sporophore of the mushroom to identify external structures. Spore-prints can be produced and studied first with a magnifying glass and then with a microscope. The study of the life cycle of the mushroom can reinforce the understanding of the concept of “structure and function”. A discussion on the food value of mushrooms is useful in this topic. There is no easy rule by which an edible mushroom may be at once distinguished from a poisonous one. To further their general appreciation of plant development, students can study how mushrooms are grown commercially.

Suggested terminology: *sporophore, spore-print, edible.*

S13.5: Parasitic fungi

In this topic, students should grasp the idea that many fungal parasites are important because of their effects on humans, animals, and plants. Only a general understanding of mildew, blights, apple scab, and wheat rust is considered important in this topic. Human control over apple scab and wheat rust should be emphasized to provide students with an appreciation of our attempt to control our environment. One life cycle should be studied in some depth to indicate how we have somewhat successfully attacked the problem of parasitism, and how nature continues to select more successful parasites.

Suggested terminology: *mildew, blight, scab, rust.*

S13.6: Lichens

A lichen is an association of an alga and a fungus. This relationship is an example of symbiosis. Students should have some knowledge of the generally wide habitat of lichens and be able to account for this situation. An examination of crustose, foliose, and fruticose lichens, using slide cross sections, will give students the opportunity to study the appearance, composition, and reproduction of lichens. The significance of lichens should be discussed in terms of succession. Students can observe collected lichen specimens for a three-week period. On the basis of their personal observations, they can discuss the ways in which lichens illustrate symbiosis.

Suggested terminology: *lichen, symbiosis.*

S13.7: Complex algae

The plant kingdom includes many-celled organisms with cells that are specialized so as to form different tissues and systems. The cells have rigid walls of cellulose and they contain chloroplasts. There is an alternation of sporophyte (2N) and gametophyte (N) phases in the life cycle. Some algae fit these specifications. The red, brown, and green divisions include such representatives as fucus, chlamydomonas, spirogyra, ulothrix, and ulva. Students should examine a variety of forms to show how complex algae are classified and how they complete their life cycles.

Suggested terminology: *sporophyte, gametophyte, tissue, system.*

S13.8: Mosses

Students should appreciate that mosses are of special interest to biologists because they were possibly the first land plants (although they have not fully adapted to a terrestrial environment). They should study the gametophyte and sporophyte plants using specimens of moss or leafy shoots (living or preserved) that contain mature spores, stalks, and capsules. They can briefly study the life cycle of moss in order to understand the term "alternation of generations". This topic could lead to a study of regional species where students would summarize their observations in a series of drawings or photographs.

Suggested terminology: *gametophyte, sporophyte, alternation of generations.*

S13.9: Ferns

This topic, as well as others in this unit, allows the student to develop good laboratory techniques in slide preparation and the use of the microscope. Using freshly collected or potted sporophyte fern plants, students should observe and make detailed drawings of a fern sporophyte. There are several microscope techniques in this topic that can be introduced in the laboratory work. Students can observe the bursting of a sporangium when glycerin is added to the water medium containing sporangia. Spores can be germinated in a humid environment, and the gametophyte can be studied. An examination of a prepared cross section of a fern rhizome can allow students to identify such tissues as phloem and xylem, pith and epidermis. Students can consider why ferns are unable to compete with the more highly developed flowering plants. Using a hand lens, field notebook, and taxonomic key, they can do a field study of local ferns. This study should show them the importance of structural characteristics in the identification of organisms. These characteristics include the general form and structure and the distribution of the sori, the sporangia, and the form of the frond.

Suggested terminology: *sporangium sorus, rhizome, phloem, xylem, pith, epidermis.*



UNIT S14: GEOMETRIC OPTICS

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
S14.1 Sources of light	1
S14.2 Transmission of light	1
S14.3 Speed of light	1
S14.4 *Plane reflection	2
S14.5 *Curved mirrors	4
S14.6 *Refraction	2
S14.7 Lenses	3
S14.8 *Dispersion and colour	2
Review and evaluation	2
	18

Preamble

We seem to take light for granted, for in the day-time it is all around us and at night it is easy to flip on a light switch. Without light we could not see, no matter how healthy our eyes might be. Perhaps this unit could be introduced as “seen” from a blind person’s point of “view” to help students appreciate the wonder of vision, the essence of light, and the good fortune we have in being able to see – those of us who can.

Light enables us to make scientific observations and to extend our senses with the use of telescopes and microscopes.

What is light? How does it behave? How is it related to other forms of energy? Some of these questions should be considered here, for this unit is the foundation for further studies in optics in later years.

The unit on Light (Unit E12) may have been taught in Grade 7 or 8. If so, students will have studied such topics as sources, transmission, propagation, and reflection of light. Certain aspects of colour may have been included. If so, the review of previous work should be brief. If students have not studied Unit E12, such topics as transmission, propagation, and reflection can be introduced and blended here as this more advanced unit is developed.

The title of this unit suggests that geometry is involved. Students should produce precise and meaningful graphics to represent optical phenomena. Good results can be achieved if diagrams are drawn accurately.

Practical applications of optical devices should be stressed: plane and curved mirrors, prisms that reflect, and lenses that refract play an important role in our lives. The science of colour is useful, particularly to students who aspire to be artists and decorators. In this unit, the importance of energy could be emphasized.

Students who complete this unit should be able to recognize a variety of sources of light and to note how different kinds of media affect its transmission. They should know the laws of reflection and refraction and be able to locate the images formed by mirrors and lenses. Student experiments with mirrors, prisms, and lenses are essential to this study. As well, students should understand simple explanations that might account for such phenomena as refraction, the creation of many colours from a few, or the blending of colours to form white light. However, treatment of the particle, wave, and quantum theories should not be attempted here.

S14.1: Sources of light

While sources of light may have been treated in Grade 7 or 8, this topic will give more insight to the subject, if it is approached from the energy-conversion point of view. Students should recognize the difference between luminous and non-luminous objects and between natural and artificial light sources. What forms of energy can be converted into light, and what are some of the applications of such transformations?

Suggested terminology: *luminous, non-luminous, artificial, normal.*

S14.2: Transmission of light

Students should be aware of the three types of media: transparent, translucent, and opaque. The fact that light requires no material medium for its transmission and that it travels in straight lines may be illustrated. The formation of shadows – umbra and penumbra – can be seen by students.

Suggested terminology: *transparent, translucent, opaque, umbra, penumbra.*

S14.3: Speed of light

The fantastic speed of light (3×10^8 m/s) should be discussed. If a beam of light could be bent so that it travelled around the earth, it would circumscribe the earth more than seven times in one second. How can light be clocked so that its incredible speed may be determined? One or two methods should be considered. A model or illustration might be devised to illustrate such techniques.

S14.4: Plane reflection

The laws of reflection might be “discovered”, stated and verified experimentally, or merely re-viewed. Time should not be wasted if this concept is familiar to the students. Correct terminology should be used. Regular and diffuse reflection should be demonstrated.

The positions and characteristics of images formed by plane mirrors should be determined through student experimentation. Ray diagrams should be drawn accurately to show how to locate an image formed by a plane mirror based on the laws of reflection.

Suggested terminology: *angle of incidence, angle of reflection, incident ray, reflected ray, normal, regular and diffuse reflection, object, image, virtual, real, erect, inverted.*

S14.5: Curved mirrors

The terminology related to curved mirrors should be explained. Students often seem to have difficulty in locating images formed by curved mirrors (and lenses) when using the optical bench or similar apparatus. It is generally necessary to give students clearer instructions than those found in most textbooks. Students need ample time to develop the skill necessary to locate images properly, particularly in locating virtual images.

The method of no-parallax should be mastered. Demonstrations by the teacher are not nearly as effective as student experimentation.

Students should tabulate their observations, indicating the locations and characteristics of the images for various object distances. Some students may be encouraged to design their own table to give them a chance to practise tabulating. Others will require teacher guidance in filling in a table such as the following:

Location of		Characteristics of image		
Object	Image	Size	Kind	Attitude
At a great distance	Stated in the same terms as the object distance, e.g., at $2f$	Expressed in relation to the object's size: same, larger, or smaller	Real or virtual	Erect or inverted
At $2f$				
Between $2f$ and f				
At f				
Between f and mirror				



Ray diagrams can be used to show the formation of images by curved mirrors based on the behaviour of light. Applications of curved mirrors, including the parabolic mirror, are of interest and could be discussed.

Suggested terminology: *concave, convex, spherical mirror, vertex or optical centre, principal focus, principal axis, centre of curvature, focal length (f), parallax.*

S14.6: Refraction

The observation of the refraction of light through water or glass could be used to introduce this topic. Students should trace the path of light that passes through an interface from one transparent medium to another. A generalization should be formed, based on the observed behaviour of the rays of light that enter denser or less dense media. Students should also be able to trace the path of light through a triangular prism (a) in which the light is refracted at two interfaces, and (b) in which the light is internally reflected. The periscope serves as an excellent example of total internal reflection.

Depending on the ability of the students and the time available, this topic may be treated in further depth. The following activities may be considered as optional:

- an explanation as to why refraction occurs;
- graphing the angle of refraction against the angle of incidence for a series of angles of incidence from about 10° to 80° ;
- comparing semi-chords in a refraction circle diagram and plotting a series of results;
- defining and determining the index of refraction based on semi-chords, not on trigonometric ratios;
- observing, defining, measuring, and explaining the critical angle in examples of internal reflection.

Suggested terminology: *angle of refraction, interface, internal reflection, periscope.*



S14.7: Lenses

Lenses may be treated in any suitable depth as time permits. Students should locate images formed by lenses, tabulate image positions and characteristics, and develop ray diagrams to show how lenses form images. Without necessarily explaining optical devices by means of complex ray diagrams, some simple applications of lenses could be mentioned and discussed.

Suggested terminology: *converging, diverging.*

S14.8: Dispersion and colour

This topic should deal with various colour effects. Some effects that may be considered are:

- the dispersion of white light into a spectrum by means of a prism;
- the recombination of the spectrum into white light by means of a second prism;
- the use of coloured filters to produce a variety of lighting effects;
- the mixing of coloured lights in contrast to the mixing of coloured pigments;
- the appearance of coloured objects under coloured lights.

The additive and subtractive colour theories could be considered.

Suggested terminology: *dispersion, spectrum, recombination, additive, subtractive.*

UNIT S15: HUMAN INTERACTION WITH THE BIOSPHERE

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
S15.1 *The biosphere	1
S15.2 *Human characteristics	3
S15.3 Ecology of early and modern humans	3
S15.4 *Population growth	3
S15.5 *Values and attitudes	4
Review and evaluation	2
	16

Preamble

This unit is designed to strengthen the student's understanding of the position of humans within the global ecosystem. How is our uniqueness a factor that influences and is influenced by our environment?

Topic S15.3 is intended to provide an overview of our influence on the biosphere from the historical past to the present. It is hoped that this unit will provide opportunities for research, discussion, and debate. Interdependence of Living Things (Unit E4) and Populations and Communities (Unit S7) are suggested prerequisites to this unit.

S15.1: The biosphere

The concept of the biosphere as a global ecosystem should be developed. From previous observations of food chains and food webs (see Unit S7: Populations and Communities), students should be able to suggest that people are part of the earth's food web and that we affect and shape this web as does every other living organism. Students might further suggest that humans differ from other living organisms, both as an organism and as a member of a food chain or food web. Students can hypothesize on how humans are unique within the global ecosystem. For example, we can control, regulate, and utilize energy resources and we can make use of almost all food webs. What is the significance of this? Humans can destroy the balance of nature. How are humans affected in turn?

Suggested terminology: *food, values, aesthetics.*

S15.2: Human characteristics

Students can suggest the ways in which the human being is a unique organism within the animal kingdom. How do we differ from other organisms in our community? Answers to this question include the fact that the human being lives exclusively on the ground, possesses a means of communication, and has the ability to make and use a variety of tools. Students may also suggest that primates, including humans, have more distinctive features than do other animals. For example, primates have well-developed arms and hands; since the thumb of primates is opposable to the fingers, their hands can be used for grasping; and the eyesight of primates is well developed and their vision is stereoscopic. The primates are known as the "erect mammals", since most primates can walk erect if necessary.

S15.3: Ecology of early and modern humans

The modern human is given the name *Homo sapiens* (wise man). It is postulated that early representatives of this species, Cro-Magnon humans, possibly appeared about 40 000 years ago. Students may theorize on the relationship of early humans to their environment. What niche(s) did they probably occupy in the food web? Were they herbivores, carnivores, or omnivores? What were their sources of food and their methods of obtaining it? Students should be able to suggest that early humans could find food almost anywhere and could take conscious steps to obtain it. To what extent did the ecosystem of early humans encompass the surface of the earth? Were they polluters of their environment? Students could suggest how cultural changes, and finally civilization, have determined

and been determined by the position of humans in the ecosystem. These changes might include the development of agricultural practices and animal husbandry, the Industrial Revolution, and, more recently, the atomic era. The fact that humans have an ever-increasing influence on the global ecosystem due to advances in communication, transportation, and industry should be stressed. Today, every individual is a part of the global ecosystem.

Suggested terminology: *global ecosystem, Homo sapiens, Cro-Magnon human, niche, herbivore, carnivore, omnivore.*

S15.4: Population growth

Students could research recent data that describe the growth of the world's population. They might be asked to compare the growth of populations in both developing and developed countries. Countries such as India, Canada, and Sweden might be included.

Students might research the mechanisms by which natural populations maintain self-regulation. Such mechanisms could include: food supply, competition for space, disease, predation, and parasitism. Students might be asked to consider to what extent these natural controls determine the size of human populations. They can discuss the burdens placed on the global ecosystem as a result of the rapidly increasing world population, and

diminishing natural resources. How can we change our utilization of the world's resources, both renewable and non-renewable, for the benefit of all? Opportunities may be provided to describe and discuss some of the programs, including their rationales and problems, that have been initiated to regulate population size. Have all of these programs been effective? If not, why not? It should be emphasized that there is no single solution to the problems of overpopulation.

S15.5: Values and attitudes

Even though we have provided the world with new drugs, electric power, flood control, methods of irrigation, and numerous other advances, such advances have the potential to harm the ecosystem in which we live. Students might be asked to discuss the beneficial and harmful influences of the use of technology by humans. Students may also make suggestions regarding the resolution of some of the consequent problems. They can collect, study, and discuss newspaper and magazine articles relating to their environment. Debate on biological, ethical, financial, and economic issues with regard to local, national, and world problems involving human interaction with the biosphere should be encouraged. It is suggested that the use of resource personnel would broaden and clarify student opinion and knowledge.



UNIT S16: MACHINES

†Four of the topics marked with a dagger are mandatory.

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
S16.1 *Review of machines	3
S16.2 †Experimental study of a pulley system	4
S16.3 †Experimental investigations of a machine	4
S16.4 †Forms of energy in machines	4
S16.5 †Electric project	4
S16.6 †Thermal efficiency	4
S16.7 †The operation of a machine	4
S16.8 †Machine problems	4
Review and evaluation	2
21	

Preamble

This unit may be used as a continuation of Simple Machines (Unit E17). In fact, the first topic or two may be treated as a review of, or possibly an introduction to, the study of machines.

A major feature of this unit is the opportunity it provides students to study a machine on their own with some guidance from the teacher. Students may wish to design and construct a machine. The submission of a realistic project based on practical design or experimentation is something that the teacher may well encourage.

Measurement of energy – mechanical, electric, and thermal – can play an important role in this study. Beyond merely measuring and operating a machine and knowing the underlying scientific principles of its operation, students should contribute ideas on the advantages and disadvantages of various machines, taking into consideration the contemporary public concerns in such areas as safety, cost, pollution, and the wise use of energy.

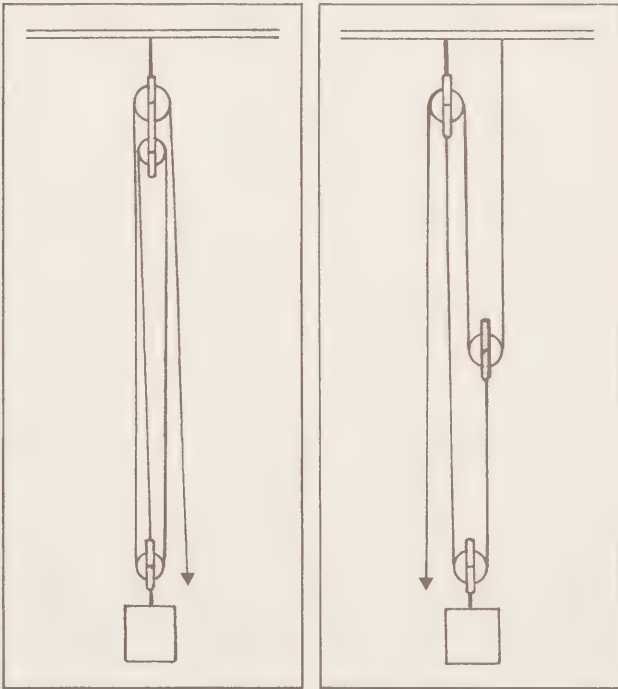
S16.1: Review of machines

Through an experimental study of a suitably complex set of pulleys arranged to lift a load, students may be introduced to or recall ideas and concepts such as: (a) the meaning of a machine as an energy or work converter; (b) the fact that work input = useful work output + wasted energy; (c) the effect of friction on the efficiency of a machine; (d) the mechanical advantage of a machine.

Suggested terminology: *machine, work input, work output, efficiency, friction, mechanical advantage.*

S16.2: Experimental study of a pulley system

Using a pulley system, students should measure the input and output forces and distances. They should then calculate the work input and output and the efficiency and mechanical advantage of the pulley system for a series of different loads lifted by it. They may be able to determine that part of work input that is used to overcome friction. This should afford a good exercise in tabulating data and graphing the results over a series of loads. Students may wish to try different combinations and arrangements of pulleys and make a comparison of their mechanical advantages.



S16.3: Experimental investigations of a machine

The purpose of this topic is to give students the opportunity to design their own investigations to answer questions related to mechanical machines. The practical work here will depend on the equipment and time available and on the attitudes of the teacher towards individualized or group work. Students, individually or in groups, should set up a machine such as a pulley system (different from any previously used), a pulley with wheel and axle, a set of interconnecting levers, a group of gears, or a double wheel and axle. They should then seek to answer such questions as the following:

- Is this machine related to other kinds of machines? What subtypes of this machine are there?
- What are the forces exerted on the machine, within the machine, and by the machine? Can these forces be illustrated by a force diagram?
- What is the efficiency of this machine?
- Can the efficiency of the machine be improved? If so, the needed changes should be made and the efficiency rechecked.
- Does the mechanical advantage of the machine remain the same over a wide range of loads?
- Where does the loss of energy due to friction occur in this type of machine?
- Do different types of lubricants appreciably affect the machine's efficiency?
- What is the magnitude of the percentage error in measurements and calculations?
- What are some of the practical applications of the machine?
- What are the advantages and disadvantages of this particular kind of machine?
- Are there other questions that may be posed for investigation?

S16.4: Forms of energy in machines

A toaster converts electric energy to heat and light. An electric bell converts electric and magnetic energy into mechanical and acoustic energy. Students should provide a good number of examples of machines that convert one form of energy into another. "Transformation of Energy" may be the title of a project. The machines to which the students refer in this project should be among those that are within their experience. Such machines may be found in the home, the school, travel, the plaza, neighbouring industry, or recreational areas. Students should realize that less complex things, such as a child's swing or a pencil sharpener, are energy converters and machines as are more complex constructions, such as supersonic jets and hydro-electric generators. The project should identify the forms of energy input and output for each machine listed. Perhaps the function of each

machine might be included and a value judgement made as to the need or desirability of such machines in our society. In some cases, examples of reverse transformations of energy may be paired together. For example, a windmill generator converts the energy of the wind into electricity; in the operation of an electric fan the reverse takes place.



S16.5: Electric project

This topic will give students an opportunity to design and construct a machine that has a measurable input and output, one of which is electric. The following are two possibilities: a simple electric generator that is operated by pulling a cord wound round its axle; an electric motor that is used to operate a simple pulley. Students could measure the energy input and output of the machine and could determine the machine's overall efficiency. The mechanical energy of the machine may be determined through the relationship between a joule and a newton metre. The electric energy could be measured through the relationship between a joule and a watt second or a volt ampere second. These ideas will likely require some explanation if they have not been covered in a previous unit. This will necessitate the co-ordination of various topics within the curriculum.

S16.6: Thermal efficiency

If they are careful to take the proper precautions to prevent short circuits and electric shock, students can determine the thermal efficiency of heating some water by means of an immersed light bulb. Is this an efficient way of heating water? Students should try to predict the efficiency in advance. The electric energy input in joules equals the wattage of the bulb times the time in seconds.

The thermal output to the water may be determined from the fact that it takes about 4.2 kJ (kilojoules) to raise the temperature of a kilogram of water through 1°C. Various types of immersion heaters may be used to compare their individual efficiencies. This exercise may be extended to make a rough verification of the specific-heat capacity of water in joules per kilogram degree Celsius. Again, this topic should be co-ordinated with the work done in Heat (Unit S5).

S16.7: The operation of a machine

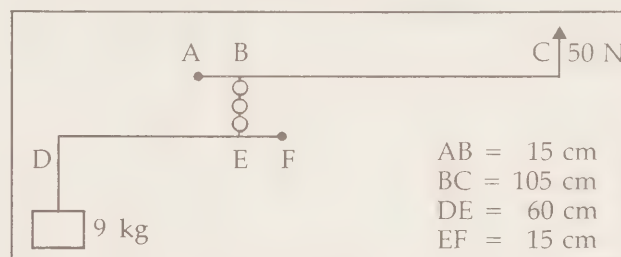
How does a machine work? To answer this question, students may work individually or in small groups and examine a manufactured machine. Such machines should be approved by the teacher, who should ensure that they are not operated without supervision and a full knowledge of safety precautions if there is any likelihood of danger whatsoever. Machines (preferably old ones) may be brought to school by the students or may be borrowed from various departments within the school. In some cases, cutaway models may be available. Some machines may be partly disassembled, but only with the permission or under the supervision of the teacher. Examples of machines for possible consideration include the following: a bicycle, an electric bell, a sewing machine, a steam engine, a typewriter, an electric drill, an electric beater, a vacuum cleaner, a water pump, an electric-door motor, a hand lawn mower, a can opener, a brace and bit, a post-hole digger, a carburetor, parts of industrial machines, and some farm implements. Students should be able to prepare a report including such data as: (a) sources of energy input; (b) kind(s) of energy output; (c) a diagram of the machine or of its main working parts; (d) a description of how it operates; (e) an identification of those parts that may be classified as simple machines; (f) an estimate of the efficiency of the machine; (g) the applications and importance of the machine; (h) the cost of the machine compared to its economic benefit; (i) the need for the machine in modern society in the face of the energy crisis; (j) the disadvantages of the machine; (k) any danger areas and safety features; (l) a brief account of what we would do if this machine did not exist.

S16.8: Machine problems

This topic may be devoted to the solution of some kinds of problems that may not appear elsewhere. The following examples illustrate some possibilities:

a) Moments

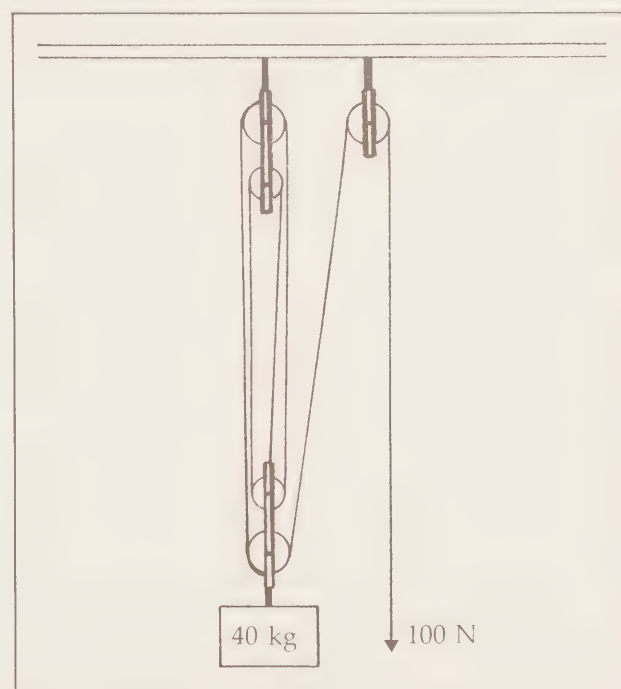
Is the 50 N force sufficient to support the system shown below? Assume that the force of gravity on the levers and chain is negligible.



(Answer: No)

b) Ideal and actual mechanical advantage

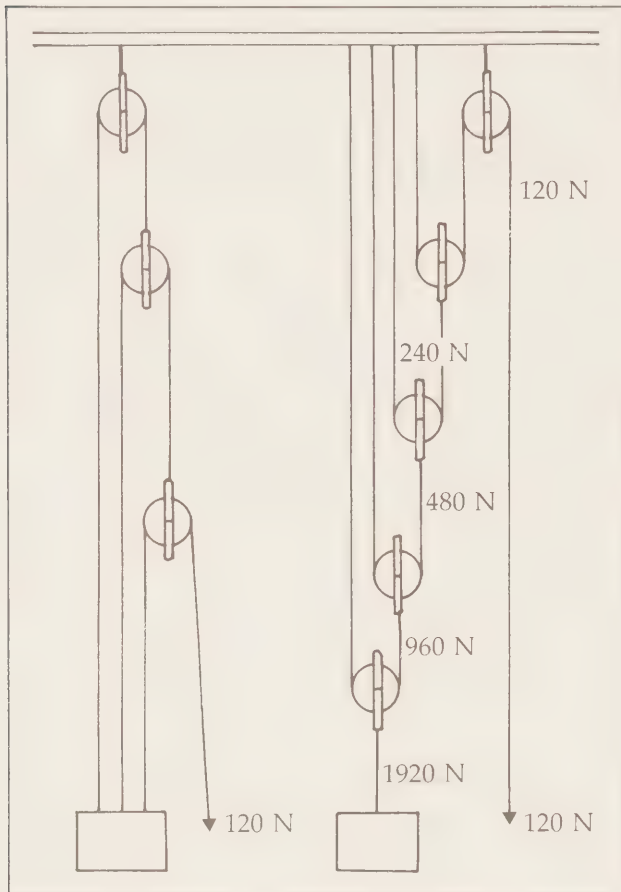
This pulley system lifts a 40 kg mass through a height of 4.8 m when 24 m of rope is hauled in by the operator. The operator exerts a vertical pull of 100 N on the rope when operating the pulley. What is the ideal mechanical advantage (I.M.A.)? What is the actual mechanical advantage (A.M.A.)? What is the efficiency? How much energy was wasted, such as in overcoming friction?



(Answers: 5, 4, 80%, 480 J)

c) Force analysis

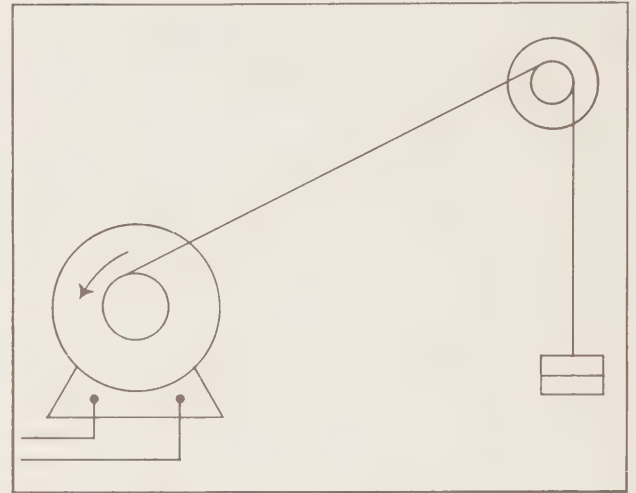
Show the force (tension) in each segment of the ropes in these two pulley systems. Then deduce the total force used to lift the load. Disregard friction and the force of gravity on the ropes and the pulleys. *Note: On each pulley the upward forces are equal to the downward forces.*



(Answers: 840 N; for the second diagram the answers are written in.)

d) Electrical and mechanical energy

A 1.0 kW motor operates for 20 s and lifts an 80 kg mass through a height of 18 m by means of a wheel and axle. What is the energy input, energy output, energy loss, and efficiency of the system?



$$P = 1.0 \text{ kW} = 1000 \text{ W}$$

$$t = 20 \text{ s}$$

$$F = 80 \text{ kg} \times 10 \text{ N/kg} = 800 \text{ N}$$

$$d = 18 \text{ m}$$

$$E_{\text{input}} = Pt = 1000 \text{ W} \times 20 \text{ s} = 20\,000 \text{ J} = 20 \text{ kJ}$$

$$E_{\text{output}} = Fd = 800 \text{ N} \times 18 \text{ m} = 14\,400 \text{ J} = 14 \text{ kJ}$$

$$E_{\text{loss}} = 20\,000 \text{ J} - 14\,400 \text{ J} = 5600 \text{ J} = 5.6 \text{ kJ}$$

$$\text{Efficiency} = \frac{E_{\text{output}}}{E_{\text{input}}} = \frac{14\,400 \text{ J}}{20\,000 \text{ J}} = 0.72 = 72\%$$



UNIT S17: MECHANICS

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
S17.1 *Force	1
S17.2 *Gravity-mass ratio	1
S17.3 Friction	2
S17.4 Coefficient of friction	1
S17.5 *Balanced forces	2
S17.6 Unbalanced forces	1
S17.7 Moment of force, torque	3
S17.8 *Work	1
S17.9 *Power	3
S17.10 Energy	2
S17.11 *Pressure	2
Review and evaluation	2
	21

The concepts of force, moment, work, power, and pressure should be related to everyday examples wherever feasible.

It is recommended that the measurement or calculation of acceleration and the mathematics of non-parallel vectors be avoided except, perhaps, for those few students for whom these topics may be appropriate.

S17.1: Force

The concept of force should be reviewed (see Unit E3). Various pushes and pulls can be illustrated with physical examples. Students should be given the opportunity to measure a variety of forces using a newton spring scale.

Suggested terminology: *force, newton.*

S17.2: Gravity-mass ratio

The concepts of mass and gravitational force and their relationship should be reviewed (see topics E3.3 and E3.4). The fact that there is a 10 N force of gravity acting on each 1 kg mass (at the earth's surface) should be recalled by a demonstration or by a student activity (perhaps with the aid of a graph). This relationship may be stated as a ratio called the gravity-mass ratio g , where $g = 10 \text{ N of gravity force per } 1 \text{ kg of mass} = 10 \text{ N/kg}$.

The force of gravity acting on a mass $= F = mg$. For example: What is the force of gravity on a 55 kg person?

$F = mg = 55 \text{ kg} \times 10 \text{ N/kg} = 550 \text{ N}$ or 0.55 kN

Note: At this stage, do not associate g with the acceleration due to gravity unless it has been previously studied. Acceleration will probably be introduced in a more advanced course in physics.

Suggested terminology: *gravity-mass ratio, newton per kilogram.*

S17.3: Friction

Students should be able to measure the applied force required initially to pull a brick in order to start it moving along a surface against the opposing force of friction. They can vary the surface, use lubricants, or insert rollers, and investigate the force required to overcome starting friction under various conditions. Sliding friction can be compared with starting friction.

Suggested terminology: *friction, starting friction, sliding friction, static friction, kinetic friction.*

S17.4: Coefficient of friction

The ratio of the force of friction to the force of gravity acting on a block may be determined. This coefficient of friction may be expressed as a decimal fraction or per cent. A practical example, taken from a lumber yard, of the coefficient of friction between pine boards, for instance, may illustrate the use of such coefficients.

Suggested terminology: *coefficient of friction.*

Preamble

This unit is closely related to such units as Force and Energy (Unit E3), Measurement (Unit E5), Simple Machines (Unit E17), Measurement (Unit S6), and Machines (Unit S16). Care should be taken to integrate the content in these units, since some are core and others are optional.

The unifying thread throughout this unit is the concept of force. Students should be conscious of the many applications of forces acting on a variety of objects around them. Some forces are static and are barely recognized; others which produce change in motion are exhibited in transportation, athletics, and industrial processes, and are a part of our everyday activities.

Simple mathematics is an important part of the study of forces, moments, work, energy, power, and pressure. The student should become reasonably proficient in calculating the magnitudes of such physical quantities in SI units.

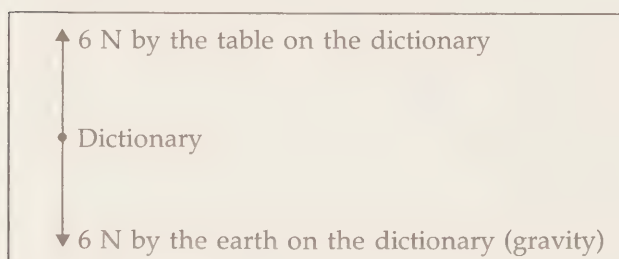
Students should be permitted to make a number of measurements in activities in which they can exert forces, do work, transfer energy, and develop power. They should also have the opportunity to consider a variety of force situations, to analyse and identify those forces that act on a particular object, and to synthesize these forces into a complete set that will account for the equilibrium of the object or for the object's change in motion.

S17.5: Balanced forces

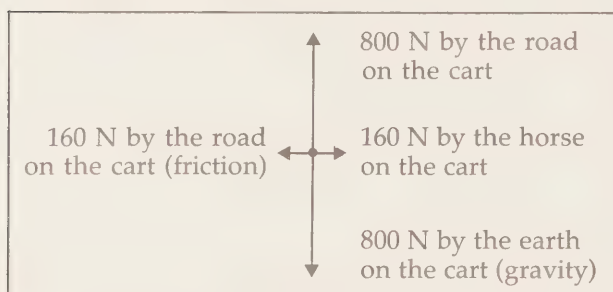
Students should consider examples of forces acting on a stationary object and ask: (a) What are the forces acting on the object? and (b) What is exerting each force?

This will involve careful reasoning as students analyse the forces. Partially completed force diagrams may be provided at first. Students should then complete the diagrams and indicate the magnitude of each force, on what it is exerted, and what exerts it. Force diagrams can be drawn to scale showing forces as vectors. (The addition of non-parallel forces is not required, but may enrich this unit of study if time permits.) The following are some examples of force diagrams:

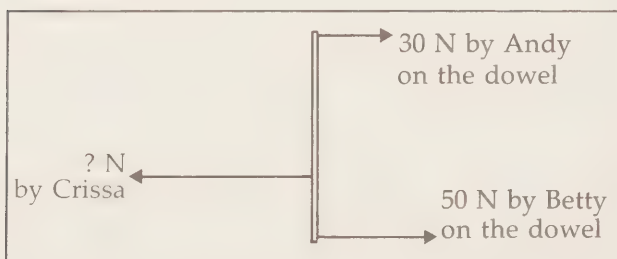
- a) A dictionary lies on a table. What forces act on the dictionary if its mass is 0.6 kg?



- b) Omit the following problem if Topic S6.4 was not covered. An 80 kg cart is pulled by a horse. The starting coefficient of friction is 20%. What forces act on the cart just as it is about to move?

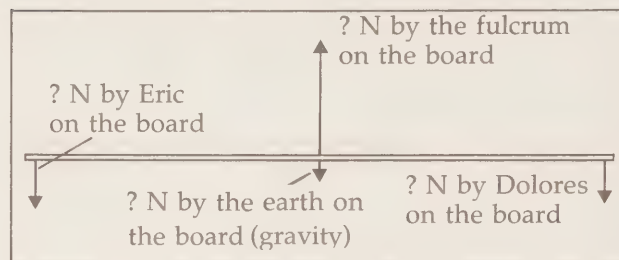


- c) Andy pulls on a horizontal dowel with 30 N and Betty pulls with 50 N against Crissa's pull in the opposite direction which is due west. Disregard the force of gravity acting on the dowel. With what force does Crissa pull if the dowel remains in equilibrium?



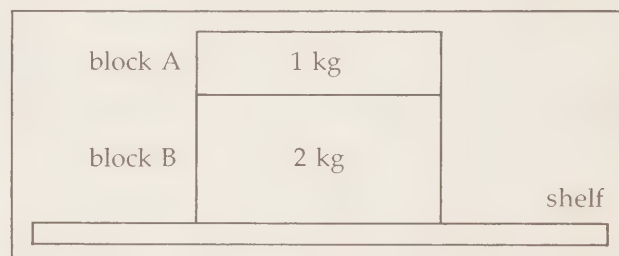
The following question may be answered at this stage or in Topic S6.7. Do you think that Crissa's pull can be applied anywhere on the 40 cm dowel and have it remain in equilibrium?

- d) A 20 kg board forms a teeter-totter with Dolores (45 kg) and Eric (55 kg) sitting on it as indicated in the diagram. What are the magnitudes of the forces acting on the board?

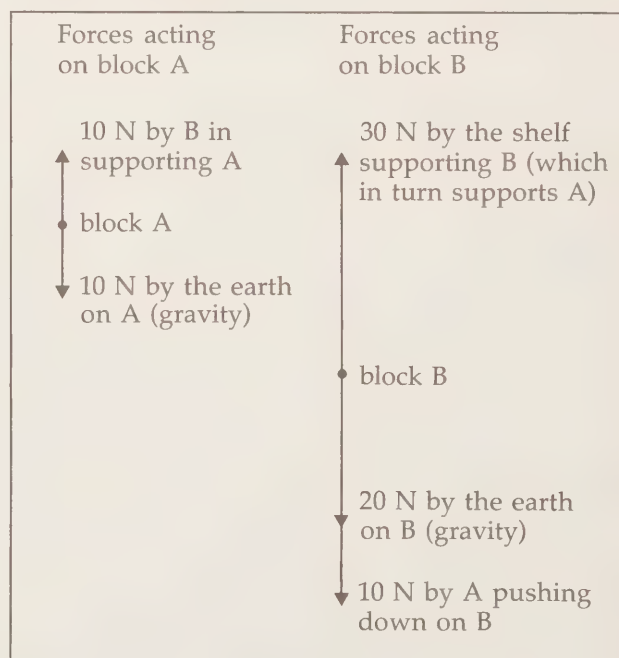


This question may be answered here or in Topic S6.7. If Dolores is seated 2.2 m from the fulcrum, about how far do you think Eric is seated from the fulcrum?

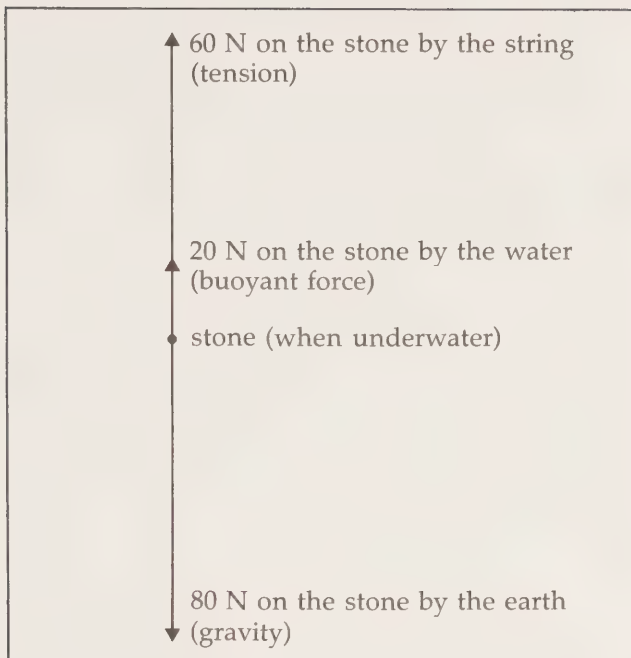
- e) Block A sits on block B which sits on a shelf as shown. What are the forces acting on A? On B?



Force diagrams to illustrate the answer may be shown as follows:



- f) The tension in a string that supports a stone in air is found to be 80 N. When the stone is suspended underwater, the tension in the string drops to 60 N. What are the forces on the stone when it is underwater?



Incidentally, using a gravity-mass ratio of 10 N/kg, students can calculate the following: the mass of the stone, its volume, and its density. This assumes that the students have previously studied Measurement (Unit S6).

Students should be able to state a necessary condition governing forces acting on a stationary object, namely, that the sum of the forces in any direction must equal the sum of the forces in the opposite direction. Examples dealing with non-parallel forces, components of forces, and forces acting on objects moving at a constant velocity are not required in this unit.

S17.6: Unbalanced forces

Students could observe the motion of a trolley (a) in which the forward applied force is greater than the backward frictional force, and (b) when it collides into a rubber-band barrier stretched across its path, which provides a backward unbalanced force. The idea that an unbalanced force acting on an object produces a change in its motion should be well established. It is recommended that examples be restricted to rectilinear motion. The determination of the magnitude of acceleration, a knowledge of Newton's second law, and a formal definition of the newton force are not required in this unit.

Suggested terminology: *unbalanced force, acceleration, deceleration.*

S17.7: Moment of force, torque

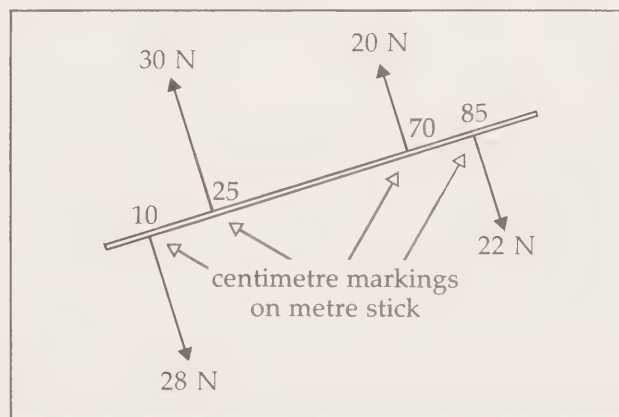
The moment of a force should be defined and illustrated with practical examples. The following terms should be introduced: *torque, clockwise, and counter-clockwise*, as well as the formula: $M = Fd$. The fact that the force and distance (in this formula) are perpendicular must be emphasized. Reference to the contrasting condition in the formula

for work, $W = Fd$, where the force and distance are parallel, should be made so that students will distinguish between the two products of force and distance. Students should realize that the preferred unit of moment of force is the newton metre and that its symbol is N•m. This newton metre cannot be equated with the joule.

Note: Strictly speaking, references to displacement rather than distance should be made in this topic. However, it is suggested that at this introductory stage the need for a rigorous treatment of vectors and their components is unnecessary. If a vector treatment is used, it might be necessary to explain the scalar nature of work W and the vector nature of moment M , with the direction of M being perpendicular to both F and d in the third dimension – a rather complex concept for science in the Intermediate Division!

The principle of moments should be applied to a few simple situations where up to four parallel forces are applied to a beam. It is suggested that students may apply parallel forces in the horizontal plane of the beam, such as a metre stick, using spring scales calibrated in newtons. If students begin with the simplest combination of three forces acting on the metre stick and then advance to more complex arrangements, they may “discover” the mathematical relationship between clockwise and counter-clockwise moments. An alternative to this would be the verification of the principle of moments in a few simple cases. If masses are suspended from the beam in the vertical plane, students should be required to draw force diagrams in which the forces are shown in newtons, not grams or kilograms. The gravity-mass ratio of 10 N/kg would then prove useful.

Problems involving moments can include many practical applications using examples of the lever and the wheel and axle. The different kinds of simple machines and the classes of levers need not be a part of this unit. It is intended that problems on moments be relatively simple. The following problem may be considered as fairly advanced and not suitable for all students.



Is this metre stick in equilibrium? All forces shown are in the horizontal plane. (Disregard the force of gravity acting on the metre stick.)

Suggested terminology: *moment of force, torque, clockwise and counter-clockwise moments or torques, newton metre, principle of moments.*

S17.8: Work

Review the meaning of work; the method of measuring force and displacement and then calculating the amount of work done by means of the formula $W = Fd$; and the joule as the SI unit of work. (See Unit E3: Force and Energy.) Students should be able to determine the amount of work done during some given activities or they might be asked to demonstrate a task in which a given number of joules of work must be accomplished.

Suggested terminology: *work, joule*.

S17.9: Power

The definition of power as the rate of doing work could be made for students by having them devise activities in which they could determine their own wattage. Such tasks might include dragging a cement block across the floor (the block is wrapped to protect the floor), raising a load by means of a pulley, climbing a rope in the gymnasium, ascending a flight of stairs, or turning a bicycle pedal against some resistance. In this last example, students would have to determine the average of several readings of the tangential force required to move the pedal, the total distance travelled by the hand or foot during several revolutions, and the time elapsed. They might compare the wattage of a right arm against that of a left arm. The question of accuracy and approximation should arise in such activities.

Problem-solving should involve SI units and formulas such as $P = W/t$, and $F = mg$, where $g = 10\text{ N/kg}$ and P is expressed in watts. However, care must be taken not to overcomplicate this topic by undue emphasis on problems. Many students will have another opportunity to attempt this type of problem-solving in more advanced courses.

Reference could be made to transformations between mechanical, electric, thermal, and other forms of power.

Suggested terminology: *power, watt*.

S17.10: Energy

The relation between work and energy should be reviewed. Since $W = Pt$, it is apparent that a joule is equivalent to a watt second. This leads to a method for determining the amount of heat energy transmitted to water by means of an electric immersion heater. Students may make an approximate determination of the amount of energy required to heat up a kilogram of water through 1°C and, if desired, they may verify the specific-heat capacity of water as about $4200\text{ J/(kg}\cdot^\circ\text{C)}$.

The cost of electric energy is presently based, in most of Ontario, on so many cents per kilowatt hour [$\text{¢/(kW}\cdot\text{h)}$]. Eventually, this may change to a rate expressed in cents per megajoule (¢/MJ). Students could determine the cost per month of operating certain appliances in the school or home.

Suggested terminology: *watt second, kilowatt hour, megajoule, specific-heat capacity*.

S17.11: Pressure

Students should be introduced to the relationship $p = F/A$, where p represents pressure, F , force, and A , area.

The SI unit of pressure, the pascal (Pa), is a low pressure, and the kilopascal (kPa) is the pressure that is commonly used in many applications. Typical atmospheric pressures, tire pressures in bicycles and cars, and so on, could be discussed. The difference between absolute pressure and gauge pressure should be discussed. For example, the pressure in a car tire is 200 kPa (gauge), that is, 200 kPa more than normal atmospheric pressure, which is about 100 kPa. The total pressure in this tire is 300 kPa (absolute), but the pressure gauge reads only the pressure above atmospheric pressure. A completely flat tire would show a gauge pressure of 0 kPa, but it has an absolute pressure of 100 kPa. What is meant by a negative pressure of, say, -20 kPa? Would this be gauge pressure or absolute pressure? Problems such as the following may be worked out by the students. A cement block lying on a side that measures 20 cm by 40 cm has a mass of 16 kg. What pressure does it exert on the platform on which it is situated?

$$F = mg = 16\text{ kg} \times 10\text{ N/kg} = 160\text{ N}$$

$$A = lw = 40\text{ cm} \times 20\text{ cm} = 0.4\text{ m} \times 0.2\text{ m} = 0.08\text{ m}^2$$

$$p = \frac{F}{A} = \frac{160\text{ N}}{0.08\text{ m}^2} = 2000\text{ Pa} = 2.0\text{ kPa}$$

Suggested terminology: *pressure, pascal, kilopascal, atmospheric pressure, absolute pressure, gauge pressure*.

UNIT S18: SEPARATION OF SUBSTANCES

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
S18.1 *Direct filtration	2
S18.2 *Sedimentation	2
S18.3 *Floc formation	2
S18.4 *Simple distillation	2
S18.5 *Fractional distillation	2
S18.6 Fractional crystallization	6
S18.7 Paper chromatography	2
Review and evaluation	2
	20

Preamble

The use of pure substances — that is, those that are relatively free from impurities — forms an important aspect of daily living. The study and practice of the techniques for separating substances from their impurities form the major portion of this unit. The techniques to be studied are as follows: direct filtration, sedimentation, floc formation, simple and fractional distillation, fractional crystallization, and paper chromatography.

While this unit is intended as an optional unit of study in the physical sciences, it is important to note that in order for it to be completed successfully, students must be familiar with some of the material covered in Solutions (Unit S19). If Unit S19 is not studied, then an appropriate but short background on solutions should be included in this unit. If Heat (Unit S5) is not studied until after the completion of this unit, then an introduction to the graphing of temperature-time data, as well as the concept of constancy of temperature during a change of state for pure substances, is necessary. Since this unit emphasizes the practical study of separation techniques, evaluation should reflect practical testing, which may consist of short individual technique tests or a major practical laboratory test.

S18.1: Direct filtration

Since students are already familiar with the concept of filtration, any initial discussion should centre around examples of filtration in daily life. Common examples could include: filtration in cigarettes, furnaces, auto engines, swimming pools, aquarium pumps, and the removal of pulp when making fruit jelly. Students should be encouraged to explore other examples of filtration. While there are a large number of solid residues that can be used to illustrate direct filtration, the teacher should ensure that students are aware of the relationship between solubility and the appearance of the residue or filtrate after filtration. Students should be able to decide whether or not a filtration process would allow the separation of the solids in a mixture, given their solubilities in a chosen solvent.

Numerical precipitation problems can be profitably studied in this topic. The following is a typical problem: The solubility of potassium nitrate at 20°C is 35 g/100 g of water. If a solution containing 80 g of potassium nitrate in 100 g of water at 100°C is cooled to 20°C and then filtered, how much residue will be found on the filter paper? Teachers may wish to use sugar refining as a basis for a discussion of an industrial application of this technique.

Suggested terminology: *filtration, residue, solvent, filtrate.*

S18.2: Sedimentation

The same natural process responsible for sedimentary layers in the earth's crust is often put to use by people. Examples of such successful applications of sedimentation include septic tanks, water-treatment plants, and the separation of blood fractions. Students could work in groups to explain several such examples of sedimentation; the groups could then share their findings by reporting them to the class.

Students may study sedimentation first-hand by observing several times in a class period and again in 24 h the appearance of a large test tube to which water and a spoonful of loam soil have been added. With a little care, students should be able to observe and explain the relationship between particle size and the layer position of the sediments. Teachers may wish to expand this topic to include a demonstration of the action of a centrifuge or a detailed study of one or more industrial applications of sedimentation.

Suggested terminology: *sedimentation, centrifuge.*

S18.3: Floc formation

The extent and rate of sedimentation in water suspensions can be increased by the addition of alum to a murky water suspension. Globules of aluminum hydroxide will form and serve as a sticky base to which the suspended particles will adhere. Students should be able to perform simple experiments to demonstrate the use of an alum (aluminum sulphate) solution to increase the rate of sedimentation by floc formation. These large particles of aluminum hydroxide and the suspended impurities may then settle out as a sediment or may be filtered from the water. The addition of lime serves as a source of hydroxide ion in a solution that may be below a pH of 7. A student whose parents own a swimming pool may explain the practical use of floc formation for the class. Alternatively, teachers may wish to invite their local pool-maintenance staff into the classroom to discuss the application of this process.

Floc formation is also used in the refining of sugar. Hence, this process can be tied in with that of filtration previously mentioned in relation to sugar refining.

Suggested terminology: *floc, pH, hydroxide ion, alum.*

S18.4: Simple distillation

The desalination of sea water in areas where fresh water is in short supply can serve as an excellent introduction to the topic of distillation.

In schools where distillation flasks and Liebig condensers are in short supply, it is suggested that a round-bottom flask fitted with a rubber stopper, a glass elbow, and a rubber delivery tube will work quite nicely, provided that the collecting flask is immersed in a sink of cold water. Care should be taken to remove the hose from the collecting flask before shutting off the supply of heat. If this is not done, a partial vacuum created by the cooling air space will permit the cool distillate to re-enter the hot flask with possible explosive consequences.

In order to make the progress of a simple distillation of a salt solution more visible to the students, a coloured-water solution of bluestone or potassium permanganate may be used. Caution must be exercised when handling these chemicals; the solutions must not be heated to dryness.

Under no circumstances should students be permitted to taste any distillate produced. If verification of the absence of salt in the distillate is deemed necessary by the students, evaporation of a small portion of the distillate may be carried out. From such investigations, students should be able to manipulate the appropriate apparatus and understand the process of separating a solvent from a solid-liquid solution by simple distillation.

Suggested terminology: *distillation, distillate.*

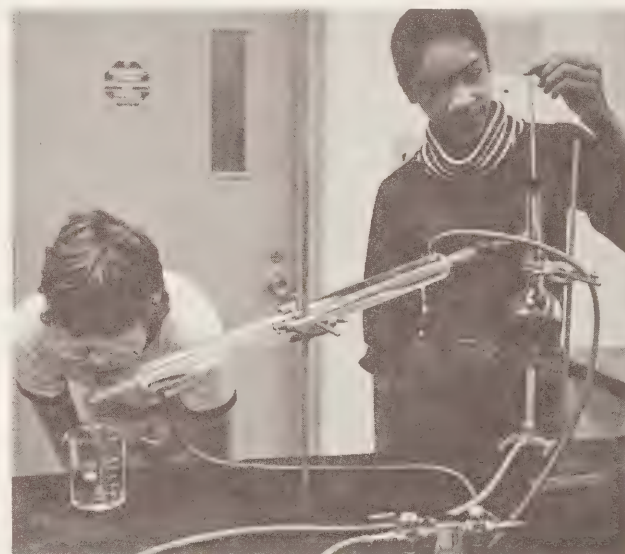
S18.5: Fractional distillation

The separation of liquids in a mixture or solution may be accomplished by fractional distillation. A useful choice of liquids for a fractional-distillation investigation is a 60/40 solution of water and isopropyl alcohol. *Caution: Isopropyl alcohol is flammable.* Students can plot a vapour temperature-time graph from simple distillation data to determine the number of fractions to be collected and at what temperatures to change the collecting flasks. A follow-up distillation for each fraction collected could serve as a good check for purity. The fraction is probably pure if it has a sharp boiling point.

Students should recognize that significant differences in boiling point are necessary if this technique is to be successfully employed. Students can further their understanding of fractional distillation by studying a fractionating column, which may be used to illustrate the processing of crude oil into such fractions as gasoline, kerosene, and diesel fuel.

In addition, teachers may wish to discuss the bottled-gas industry where gases are obtained by fractional vaporization of liquified air.

Suggested terminology: *fractional distillation, fraction, fractionating column.*

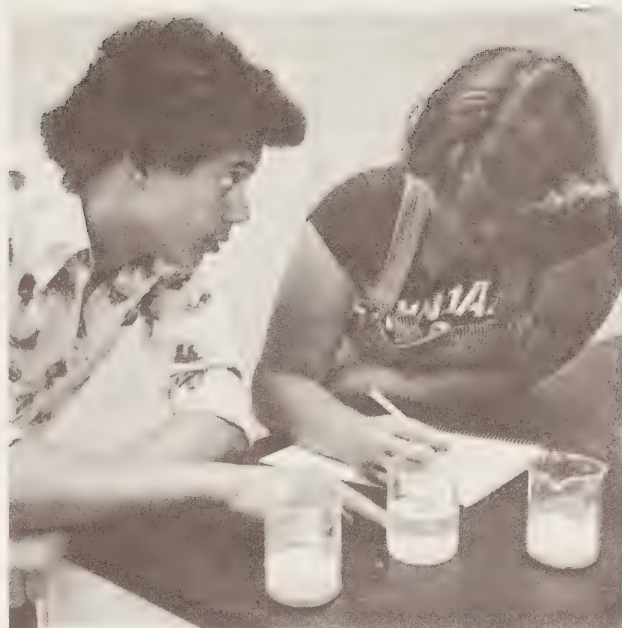


S18.6: Fractional crystallization

Although separation by direct filtration relies upon the insolubility of one of the components, it is possible to separate two solids that are both soluble, providing that one of the solids is more readily soluble at a higher temperature than the other. Students can separate by fractional crystallization a mixture of sodium chloride and potassium nitrate. A solution of the mixture is concentrated by boiling it until the volume is reduced by one-half. The resulting mixture is then filtered; the residue is the first solid. The filtrate is then allowed to cool. This causes the second solid to precipitate. Alternatively, a hot solution of the mixed solids is allowed to cool and the resulting mixture filtered. Evaporation of the filtrate results in the collection of the second solid. Separation is not complete in either of these methods. Students should know that a seemingly pure solid may be tested for purity by attempting fractional crystallization to determine if a second solid is present. Teachers may discuss the refining of rock salt as an excellent and important example of fractional crystallization as it is applied in industry.

On the completion of this topic, students should be able to determine whether two solids can be separated by fractional crystallization, given their solubilities at different temperatures in a chosen solvent.

Suggested terminology: *fractional crystallization*.



S18.7: Paper chromatography

Many students may already be familiar with the rainbow of colour on their notebooks after getting them wet. If there are some who have not noticed this, the teacher may “borrow” a page of notes from someone who has used a suitably coloured ink to demonstrate the phenomenon of pigment separation. Paper chromatography may be used by students to separate the pigments of many plants and foodstuffs. A solution of acetone and methanol has been found quite useful as an extraction solvent. Students should be provided with several strips of filter paper so that they can carry out separations in their own homes. They can test the purity of a coloured liquid using this technique.

Students may calculate the R_f value of a pigment by dividing the solvent distance travelled into the pigment distance travelled, provided that the solvent has not changed or been allowed to run off the paper column. Students may identify pigments if they are provided with an appropriate table of R_f values.

Suggested terminology: *paper chromatography*, *pigment*, *R_f value*.

UNIT S19: SOLUTIONS

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
S19.1 *Solutions and mixtures	1
S19.2 *Molecular explanation of dissolving	1
S19.3 *Concentration	3
S19.4 *Classes of solutions	1
S19.5 *Solubility	4
S19.6 *Volume change on mixing	1
S19.7 Solubility of gases in water	1
S19.8 Problems in solubility	2
S19.9 The effect of solutes on fixed points	2
S19.10 Solvents	2
Review and evaluation	2
	20

Preamble

We encounter solutions and their products every day. Throughout this unit, students will further their experiences and understanding of various solutions. At the same time, a study of solutions gives students experiences that can consolidate their knowledge of atoms, molecules, and the structure of matter. Suitable investigations further the development of the manipulative skills of measuring volumes and masses, recording temperatures, filtering, pouring, stirring, and heating. The safe use of laboratory equipment is to be emphasized in this unit. Some students may have studied Solutions (Unit E18) in Grade 7 or 8, while others who have not may require some simple explanations of terms. However, most students know intuitively that the warmer the water, the more sugar you can dissolve in it. They know that salt applied to roads in winter prevents water from freezing.

One of the goals of this unit is to encourage students to use intellectual processes to develop a model for the structure of matter. There are several possible approaches to the study of solutions; however, the concepts developed in this unit should be established by experimentation or demonstration in the classroom if possible. This unit may also be used to develop a model of matter, as presented in Structure of Matter (Unit S8), by starting with solutions, then moving into crystal growing and a study of crystal structure, and finally developing a

model of matter that can be demonstrated experimentally as being consistent. The study of solutions helps students understand the particulate structure of matter, which forms an important basis for explaining many chemical phenomena. Care should be taken to integrate the work of this unit with that of other units such as Chemical Change (Unit S2), Structure of Matter (Unit S8), and Separation of Substances (Unit S18).

S19.1: Solutions and mixtures

This topic serves as both review and introduction. A basic knowledge of solutions is established before students look at solutions in detail.

Students should learn the distinctions between mechanical mixtures and solutions. They may also compare these mixtures with suspensions and dispersions. If this latter comparison is made, it may be necessary to introduce the Tyndall effect and the terminology associated with it. To strengthen the distinction between mechanical mixtures and solutions, some methods of separation, in particular, filtration and sedimentation, may be introduced. Students should know that solutions are transparent, that they do not separate on standing or filtering, and that one cannot see the solute in a solution even with a microscope.

After establishing these characteristics of solutions, students may be encouraged to find other methods of separation. This may be used as an introduction to Separation of Substances (Unit S18).

Suggested terminology: *solute, solvent, filtrate, residue, concentration, solubility, mechanical mixture, suspension, dispersion.*

S19.2: Molecular explanation of dissolving

An explanation of dissolving may be developed based on the students' knowledge that matter is made up of atoms and molecules in constant motion. Using words and diagrams, students should be able to explain dissolving in terms of the kinetic molecular theory.

The slow dissolving of copper sulphate or potassium permanganate may be used to illustrate the dissolving process.

The kinetic molecular theory may also be used to explain the diffusion of particles in air. A demonstration of diffusion may be carried out by placing a few crystals of iodine in a large, closed Pyrex test tube and by gently heating them. The iodine will vaporize and recrystallize on the inside of the test tube, demonstrating that the molecules have moved. Care should be taken to use only a small amount of iodine crystals and to heat gently because of the toxic nature of the iodine vapour.

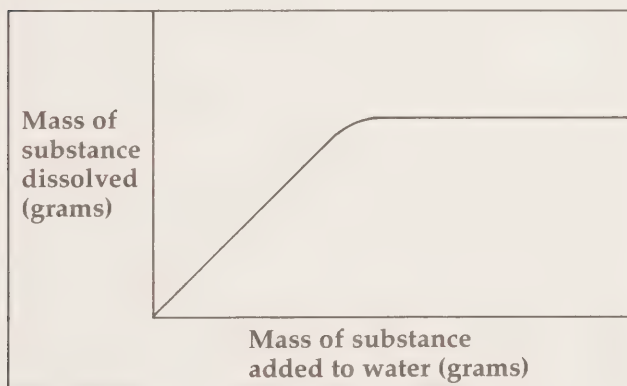
The factors affecting the rate of dissolving can be demonstrated by the teacher or the students. Students should be able to state that the rate of solution is affected by temperature, the size of the solute particles, stirring, and the chemical structure of the solute. They should be encouraged to find day-to-day activities that make use of the factors affecting the rate of solution, such as the stirring of a cup of coffee to dissolve sugar.

Suggested terminology: *kinetic molecular theory, diffusion, rate of solution.*

S19.3: Concentration

The concept of concentration is an important idea in the development of classes of solutions and solubility. "Concentration" has often been defined as "the mass in grams of solute dissolved per 100 g mass of solvent".

A class experiment may be performed in which students are given varying amounts of solute to dissolve in a given volume of water at room temperature. If water is the solvent, then 100 g of water may be obtained by simply measuring a volume of 100 mL or 100 cm³. By measuring the mass of the solute before mixing it into the solvent and then recovering and weighing the solute that did not dissolve, a class graph of the amount dissolved versus the amount added will show a plateau. This indicates that the water solvent has the maximum amount of solute that it can dissolve at room temperature.



The above-mentioned experiment could be repeated at a different temperature, such as 100°C, using a water bath, in order to show that temperature changes solubility. Other salts may be used to show that the maximum concentration also depends on the solute.

Organic solvents may be discussed as well to show that the concentration is also dependent on the solvent.

A simple experiment to determine the solution concentration may be done in class by measuring the mass of solution, evaporating the solution to dryness, and then determining the mass of the solute residue. The mass of the solvent and the mass fraction or concentration of the solution can then be calculated. Problems that involve equivalent concentrations may be discussed. The following are typical problems:

- What volume of water is needed to dissolve 80 g of salt so that the concentration at 20°C is 15 g/100 g of water? (Answer: 0.53 L)
- How much salt must be added to 80 cm³ of water to make a solution with a concentration of 15 g/100 g at 20°C? (Answer: 12 g)

Students should be able to determine, by experimentation, the solubility of some common salts in solution.

Suggested terminology: *concentration, mass fraction, solubility.*

S19.4: Classes of solutions

If the inability of solvents to dissolve an infinite amount of solute has been established, students can divide solutions into two types – saturated and unsaturated. These solutions may be defined in terms of concentration.

Students could be asked to defend such statements as "The solution is saturated," or "The solution is unsaturated." This would lead to a test for saturation that might be carried out in class.

Students should be able to prepare a saturated solution. Supersaturated solutions are unstable. A confrontation may be set up using the test for saturation with a supersaturated solution of sodium thiosulphate. Students may be encouraged to find examples of other supersaturated solutions such as honey. Students may wish to show that the temperatures of supersaturated solutions change (up or down?) as they return to their saturated state.

Suggested terminology: *unsaturated, saturated, supersaturated solution.*

S19.5: Solubility

Solubility is the concentration of a saturated solution at a given temperature. Students should discover experimentally that there is a maximum amount of a solute that a solvent can dissolve, as mentioned in Topic S19.3. They should also learn that different solutes have different solubilities. Students may do an experiment to see differences in solubilities at two different temperatures. They could make graphs of solubility versus temperature from a solubility-temperature data table. They should interpret the regions on the graph in terms of classes of solution. The convention of expressing solubility in grams of solute per 100 g of solvent should also be introduced.

The following are some typical problems involving the use of solubility graphs:

- Determine the amount of sodium chloride that will form a saturated solution with 100 g of water at 60°C.
- Determine the amount of sodium chloride that will form a saturated solution with 23 g of water at 60°C.

Other problems may involve finding the mass of solvent needed to dissolve a given mass of solute. Problems that involve cooling or heating a saturated or unsaturated solution may be included. The following problem is an example: Using a solubility-temperature graph, calculate the mass of sodium chloride that will precipitate when a saturated solution containing 50 g of water is cooled from 80°C to 20°C. A practical lab test may be developed using the concept that the solubility of a solute is a characteristic property. Students are given an unknown sample and the resources to identify it using solubilities in different solvents.

Suggested terminology: *solubility graph, precipitation.*

S19.6: Volume change on mixing

The principle of conservation of mass could be reviewed to begin this topic. Solutions may be used to illustrate this concept. However, volumes are not always conserved when liquids are mixed. If 100 mL of alcohol and 100 mL of water are placed in a large graduated cylinder, students will see that the final volume of the solution is not 200 mL. An explanation of this may be developed using the concept that different atoms and molecules have different sizes and spacings. Teachers may wish to discuss other examples of the non-additivity of volumes using other liquids, solutions, and mechanical mixtures.

Suggested terminology: *conservation of mass.*

S19.7: Solubility of gases in water

Many students are aware that as a glass of cold water warms up, small gas bubbles form on the inside of the glass and, similarly, that a warm carbonated beverage will make a louder “pop” when the bottle is opened than will an ice-cold one.

An experiment to illustrate the solubility of gas in hot and cold water may be performed using ammonia gas. The students must be cautioned not to inhale ammonia gas directly. The “ammonia fountain” might also be demonstrated to students after they have studied the solubility of ammonia. The effects of pressure on the solubility of gas may be discussed in terms of the soft-drink industry. A chart or table of gas solubilities in water may be presented to students so that they can solve simple problems involving the solubilities of gases.

Suggested terminology: *ammonia.*

S19.8: Problems in solubility

This topic includes a list of the more difficult problem types associated with concentration, solubility graphs, and the density of solutions. It is not recommended that all of these problem types be studied by an entire class. However, individual students with good ability and interest would profit from this type of problem-solving.

- Determine the amount of solute that must be added to a given solution with a given concentration to produce a solution with a new specified concentration.
- Determine the amount of solute needed to produce a saturated solution at any temperature from a given unsaturated solution.
- Calculate the new concentration if a specified mass of solvent is added to a given solution with known concentration.
- Calculate the mass of solvent that must be evaporated from a solution in order to produce a saturated solution at a stated temperature.
- Solve solubility problems in which more than one solute is in solution, assuming that the presence of one solute does not affect the solubility of the other.
- Determine the volume of a gas that will dissolve in a specified amount of given solvent, given the solubility and the density of the gas.
- Determine the final density of a solution of two liquids, given the initial densities of the liquids, their original volumes, and the volume of the final solution.

S19.9: Effect of solutes on fixed points

Students can determine the effects of impurities on the boiling point of liquids by plotting a graph of temperature-time data for the uniform heating of water and a water solution. They may also examine the effects of the concentration and the type of solute on the elevation of the boiling point of the solvent. A discussion of the use of salt on winter roads may be used to illustrate the effect of an impurity on the melting point. Teachers may illustrate this phenomenon by freezing a test tube of water using a salt-ice water bath. It is preferable to use only a small quantity of water in the test tube.

S19.10: Solvents

The effect of different solvents on the solubilities of a chosen solute may be demonstrated by choosing solvents that have considerably different effects on solubility. For example, students could compare the solubility of citric acid in water and in methanol. Applications involving different solvents may be discussed in class or assigned as projects. Examples might include: the dry-cleaning industry, household solvents, industrial and commercial coatings, the manufacture of synthetic fibres, and plumbing that uses plastic pipes.

In this topic, the importance of water solutions should be emphasized. Any discussion should include the role of water in biological systems as well as in municipal water-treatment technology.

Suggested terminology: *organic solvent.*

UNIT S20: TERRESTRIAL AND AQUATIC ENVIRONMENTS

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
S20.1 *Study of a local environment	2
S20.2 *Measurement of the abiotic environment	
S20.3 *Temperature, rainfall, and biomes	1
S20.4 Major biomes	1
S20.5 *Measurement of biotic populations	2
S20.6 *Collecting of biotic specimens	2
S20.7 Comparison studies of populations	2
S20.8 Field experiments	4
S20.9 Pond and ocean ecology	2
Review and evaluation	2
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Preamble

This optional unit is designed to provide opportunities for students to develop an understanding of ecological relationships within terrestrial and aquatic environments. Reference should be made to Interdependence of Living Things (Unit E4) and Populations and Communities (Unit S7). Some of the suggestions made in this unit might be incorporated into other units on ecology.

In this unit, emphasis is placed on developing the students' skills in measuring, in the collecting and recording of data, in the use of the library, and in making verbal and written reports.

S20.1: Study of a local environment

A local environment, such as an urban or rural community, a field, forest, swamp, or pond, should be used as the setting for the practical exercises described in this unit. Students should be informed of the clothing, writing materials, and so on that will be needed for this field work.

S20.2: Measurement of the abiotic environment

Opportunities should be provided for students to develop skill in the measurement of the following abiotic factors: temperature, moisture (precipitation), light intensity, and depth of humus at randomly selected sites of the local environment. What is the importance of each of the abiotic factors to the biotic community? The teacher may wish to have students (a) design experiments to test the effect of light and temperature on the growth of organisms (the need for a single variable and a control should be stressed); and (b) hypothesize on the relationship between plant size and altitude, moisture, or temperature.

Suggested terminology: *precipitation, humus, light intensity, abiotic, biotic, community.*

S20.3: Temperature, rainfall, and biomes

This section may be used to develop student skills in the recording of data (charts) and in the preparation of graphs. Climatograms may be developed using student data as well as data obtained from local weather stations – monthly averages of temperature and precipitation. These data can then be used to contrast and compare the temperature and rainfall of two major biomes. How is the biotic community determined by abiotic factors such as temperature and rainfall?

S20.4: Major biomes

Students could be expected to match descriptions of the biotic communities with the abiotic factors of the major biomes of the world.

S20.5: Measurement of biotic populations

Students should become familiar with several techniques used by ecologists in sampling and measuring the populations of a biotic community. For example, they may be expected to:

- calculate the density of the population in their community and to explain why it is sometimes better to describe populations in terms of density rather than of total population;
- determine the rate of population-density change (rate of change = $\Delta D / \Delta t$);

- discuss the need for two- or three-dimensional units in determining the density of populations: for example, ten cows per hectare (10 cows/ha), ten fish per cubic metre (10 fish/m³);
- compare the growth of a population of yeast with the age of the culture. The size of a population of yeast may be estimated by taking samples of the culture and then diluting the samples in order to count them under the microscope.

Suggested terminology: *density, rate of change.*

S20.6: Collecting of biotic specimens

Students should become familiar with some of the techniques used for the collecting of specimens from terrestrial, soil, or aquatic habitats. For example, it may be desirable to:

- familiarize students with the use of quadrats in gathering plant data, searching for animal data, and examining litter and soil in a forested or non-forested area (the advantage of using group data should be stressed);
- introduce students to the use of a Berlese funnel for the extraction of small organisms from litter and soil;
- have students collect and study the aquatic organisms of ponds and streams. (Simple pieces of equipment such as kitchen sieves and hand screens may be used.)

S20.7: Comparison studies of populations

Students may obtain data from the Ministry of Natural Resources on population counts of a species of interest, such as deer or wolves, fishes, or birds. Graphs can be plotted to show the annual or seasonal fluctuations in populations. These changes should be accounted for.

S20.8: Field experiments

Students can investigate the condition of a local stream or river using some of the techniques described previously. Studies of the biotic community in and around the stream or river should be made.

A study of the abiotic components of the area should include the collection of data at designated sites. Such a study could include the following: the speed of a stream, the profile of the depth of a stream, turbulence, and turbidity. If materials such as Hach kits are available, students may determine the oxygen and carbon dioxide concentration of the water. What inferences can be made about the condition of the stream from the data collected? What evidence is there of external factors that may play a role in determining the type of plant and animal life in and around the stream?

Suggested terminology: *velocity, turbulence, turbidity, parts per million (p.p.m.).*

S20.9: Pond and ocean ecology

The investigation of a local stream or river could be used as background for library research on the biotic communities of lakes and/or oceans. Students could contrast the abiotic factors influencing the type of organisms in streams with the abiotic factors influencing the type of organisms in lakes or oceans. Factors that can be considered include temperature, light penetration, and oxygen and carbon dioxide concentration. In what ways do humans have an impact on the plant and animal life in large lakes and in the oceans?

UNIT S21: VIBRATIONS AND WAVES

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
S21.1 Sounds we hear	1
S21.2 *Vibrations: qualitative aspects	1
S21.3 *Vibrations: quantitative aspects	2
S21.4 Pendulums	2
S21.5 *Waves	2
S21.6 Speed of a wave	2
S21.7 *Transmission of sound	3
S21.8 Measurement of the speed of sound	1
S21.9 Some properties of sound waves	2
S21.10 *Characteristics of sounds	2
S21.11 Applications of sound	2
Review and evaluation	2

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S21.1: Sounds we hear

This unit could well start with a consideration of the great variety of sounds we hear – perhaps a discussion of the importance of sounds and of the role of hearing in the lives of the students. A list of questions about sound may be generated by the teacher and the students to suggest an idea of the way in which a scientist may begin to think and ponder and gradually face an area of study. Students should consider whether the listed questions are good ones, whether some can be answered by logic, and whether some can lead to an investigative approach. Perhaps someone will ask the following questions:

- What is sound?
- How is it produced?
- Why is one voice louder than another?
- What makes one voice high-pitched and another low-pitched?
- Is sound a form of matter or energy or both?
- Are there “sounds” that we cannot hear?
- Why does middle C sound different on a piano and on a xylophone?
- What would it be like to lose the sense of hearing?

The point is not necessarily to answer all of these questions, but to ask them. Asking sensible questions is an important scientific process.

Suggested terminology: *sound, acoustics.*

S21.2: Vibrations: qualitative aspects

There could be a number of ways of showing that sound originates when something vibrates. This could be “discovered” by those students who are unaware of this phenomenon. Vibrations are evident in such things as:

- a drum – place dried peas on the skin;
- a violin – place small paper riders on the strings;
- a tuning fork – touch the surface of water with the fork;
- a woofer in a loudspeaker – gently touch the diaphragm.



Preamble

Sounds can bring enjoyment through music, communication through speech, warnings in traffic, hints of animal life, and the intimacy of a whisper. This unit of study aims to have students consider what causes a sound, how it is transmitted, and how we receive the sensation. This leads into a study of vibrations and waves – a study that can involve students in the continued development of the skills and processes required for experimental investigation.

Various characteristics and properties of vibrations and waves are applied to the production of sound. It is recommended that reference to electromagnetic waves be reserved for more advanced courses. This unit is somewhat introductory in nature, and care should be taken to refrain from unnecessary overlap with more advanced courses that include a detailed treatment of such topics as wave fronts, interference patterns, refraction, resonance, and particle and wave models. It is also suggested that the use of ripple tanks, Bell wave machines, and other comparatively sophisticated equipment be reserved for courses in the Senior Division.

In a day when noise pollution is a matter of concern, when many people have a keen interest in acoustic fidelity, and when telephones and tape recorders play an important role in our lives, it is worth spending some time on the study of a phenomenon that is so common in our experience.

If some vibrating objects make sounds, can it be concluded that all sounds are produced by vibrating sources? This is difficult to prove, but the formulation of a related generalization could be qualified in the minds of the students for whom the evidence is limited. To show that an inference may be more appropriate than a dogmatic generalization, the following questions might be posed:

What is it that vibrates and makes a sound when

- a door is slammed?
- the wind whistles?
- a trumpet is blown?
- a pencil writes on paper?
- a bird chirps?
- a chemical explodes?
- a car passes the school?

Two kinds of vibrations may then be introduced: transverse and longitudinal. At first, this topic may deal largely with terminology, but each term should be illustrated with a practical example. (A simple pendulum and a spring or elastic supporting a bob can illustrate these types of vibrations.) Vibrations may be distinguished from each other by kind – transverse or longitudinal (or torsional, if desired); or by comparative magnitudes of certain characteristics – fast or slow, and large or small amplitude. Through simple experiments, students can compare one vibration with another in terms of about how far the vibrating object is displaced from its rest position.

Suggested terminology: *transverse vibration, longitudinal vibration, amplitude of a vibration, displacement, rest position, one vibration or cycle.*

S21.3: Vibrations: quantitative aspects

Measurements of vibrations should be made to give students experiences in activities that involve the measurement of amplitude, frequency, and period. Definitions of these terms should be studied. The relationship between frequency and period, $t = 1/f$, should be established. The SI unit of frequency, the hertz (Hz), should be introduced. One point that ought to be mentioned is the fact that $1 \text{ Hz} = 1 \text{ cycle per second}$. In an expression such as 8 cycles per second, the term “cycles” is not considered as a unit of measure; it represents a set of events that are counted. Hence, frequency is a statement of a number of repeated or periodic events per unit of time. It does not seem to be conventionally accepted to indicate that the frequency is 8/s (meaning 8 cycles per second or simply 8 per second, with “cycles” being understood), although 8 s^{-1} and, certainly, 8 Hz are accepted. The fact that 8 Hz and 8/s are interchangeable is useful in solving problems involving, for example, the speed of sound. (See Topic S21.8.)

A student can illustrate a grasp of certain terms by doing the following activity: Place an elbow on the table, with the forearm vertical and the fingers pointing upwards. Vibrate the forearm transversely with (for example):

- an amplitude of 5 cm; of 15 cm;
- a frequency of 1 Hz; of 0.25 Hz;
- a period of 2 s; of 0.5 s.

The following question can arise out of this activity: Can the arm be vibrated in this manner so that it will actually hum? Experiments prove this to be impossible, but we may find something that will vibrate fast enough. A hacksaw blade that is clamped at its lower end and free to oscillate at its upper end will do. Initially, a small weight (such as a rubber tubing clamp) attached to the upper end of the blade will keep the frequency very low. As the position of the weight is lowered, the frequency is increased. When the weight is removed and the length of the blade is gradually shortened, the frequency is increased, and students can see and hear the effect of frequency on the production of audible sound. The number of hertz required for a sound to be heard may not be determined easily, but should be of interest. The audible range of frequencies for humans (roughly 20 Hz to 20 kHz) and for some animals may be discussed.

Suggested terminology: *frequency, period, hertz, cycles per second, audible range of frequencies.*

S21.4: Pendulums

Students may be given the opportunity to formulate hypotheses about the factors that govern the period of a pendulum. Another approach would be to have them seek answers to the question: What changes would cause a change in the period of a pendulum? Students should suggest possible variables. They could then design their own experimental techniques and determine what data they must collect and how these data should be processed and presented. Possible investigations may include the following:

- Does a change in the mass of the bob affect the period?
- Does a change in the mass of the bob affect the amplitude?
- Does a change in the amplitude affect the period?
- Does a change in the length affect the period?

Graphing can be an important part of these exercises, and care should be given to the correct use of labels and units on the axes of all graphs. Further, some students may have time to find out how two variables are related. For example, if it is found that the period of a pendulum increases as the length increases, then a problem such as the following may be asked: If the period is to be doubled, what must happen to the length of the pendulum? In this case, students should begin with a short pendulum (one that is 25 cm long has a period of 1 s), since the length has to be quadrupled if the period is to be doubled.

S21.5: Waves

Since this unit deals with sound, it may be a good idea to begin this topic with reference to longitudinal waves, rather than transverse waves. Students should be able to see equally spaced compressions and rarefactions in a spring or slinky. They should note the motion of compressions and rarefactions as they travel away from the source of vibration. The terms “wave length” and “amplitude” should be defined in reference to wave motion. Students could compare the amplitude of the vibrating source to that of one turn in the coil or slinky. The fact that energy is transmitted by a wave through a medium (without the entire medium moving from source to destination) should be stressed.

Transverse waves may be studied as another type of wave. However, this would likely be the only mention of such waves in this unit. Further work on transverse waves should probably be left to later courses in the secondary school program.

Suggested terminology: *compression, rarefaction, crest, trough, longitudinal wave, transverse wave, wave length, amplitude of a wave.*

S21.6: Speed of a wave

The speed of a wave may be determined in terms of distance and time, using the formula $v = d/t$, or in terms of frequency and wave length, using the formula $v = f\lambda$. However, this work should be taught conceptually rather than through rote memorization of a formula. If a formula is used, the inclusion of units in the solution of a problem may require special attention. The following is a sample problem: The vibrating source attached to a slinky has a period of 0.25 s, and the wave length is observed to be 60 cm. What is the speed of the waves along the slinky?

Solution:

$$t = 0.25 \text{ s}$$

$$f = 1/t = 1/(0.25 \text{ s}) = 4/\text{s}$$

$$\lambda = 60 \text{ cm} = 0.6 \text{ m}$$

$$v = f\lambda = (4/\text{s})(0.6 \text{ m}) = 2.4 \text{ m/s}$$

Note: This topic is closely related to Topic S21.8.

S21.7: Transmission of sound

A series of experiments should be attempted and/or some illustrations should be given to help students discover the factors that are required for a sound to be heard or received. Such factors are a vibrating source, a suitable medium, and a receiver or detector of sound. The following are some of the questions that may be considered:

- What kind of vibration does each of the following exhibit: a wire that is plucked, a tuning fork, an aluminum rod stroked with a damp sponge, a glass tumbler rubbed with a wet finger round the rim? (This last one may have to be based on inference.)
- Can sound travel through a gas? A liquid? A solid? A vacuum?
- How does the ear detect a sound?
- How does a microphone pick up a sound?
- Does sound travel at about the same speed through air, water, and iron?

S21.8: Measurement of the speed of sound

Sound waves have a speed of 331 m/s in air at 0°C (or 343 m/s at 20°C) with an increase of 0.60 m/s for each 1°C rise in temperature. Students may get an approximate determination of the speed of sound through a velocity experiment by timing a sound over a long distance or by using clapper-board synchronization with echoes.

In air, sound takes about 3 s to travel a kilometre, whereas the transmission of light may be considered as instantaneous. This fact can be used to estimate the approximate distance to a flash of lightning.

Simple problems on the speed of sound may be appropriate. They must be carefully selected, and challenging ones left for a later course. The following is a sample problem and solution: What is the wave length of a sound wave emitted by a tuning fork with a frequency of 256 Hz through air having a temperature of 25°C?

Solution:

$$f = 256 \text{ Hz} = 256/\text{s}$$

$$v = 331 \text{ m/s} + \frac{0.6 \text{ m/s}}{^\circ\text{C}} \times 25^\circ\text{C}$$

$$= 331 \text{ m/s} + 15 \text{ m/s} = 346 \text{ m/s}$$

$$\lambda = \frac{v}{f} = \frac{346 \text{ m/s}}{256/\text{s}} = \frac{346}{256} \text{ m} = 1.4 \text{ m}$$

Reference may be made to supersonic speeds and to mach 1 as another way of representing the speed of sound, to mach 2 as twice the speed, and so on.

S21.9: Some properties of sound waves

Among a number of properties of sound waves, the following should be discussed:

- Sound waves are longitudinal.
- Sound waves travel in all directions from a source.
- Sound waves may be reflected.
- Sound waves may be absorbed.

Suggested terminology: *reflection, absorption, normal, angle of incidence, angle of reflection.*

S21.10: Characteristics of sounds

This topic should not require an in-depth treatment in the Intermediate Division. However, students could consider the difference between noise and music, between a loud sound and a quiet one, between a low-pitched note and a high-pitched one, and between a note that has a pure tone and one that is rich in quality. Noise and music should be related to the uniformity of the wave pattern; loudness, to the amplitude; pitch, to the frequency; and quality, to the simple combination of two or more wave patterns. Problems related to the magnitude of intensity or to the superposition of waves should not be required.

This topic should be related to listening to and recognizing various sounds. Simple evaluation of the students' grasp of these concepts may be made by means of a multiple-choice test played on a tape recorder. For example: Which of the following sounds:

- has the highest intensity? (Three sounds are heard after this question and after each of the following ones as well.)
- has the quality of a violin?
- is the most musical sound?
- has the lowest amplitude?
- has the highest pitch?

Suggested terminology: *loudness, intensity, pitch, quality.*



S21.11: Applications of sound

Selected topics may be discussed or studied in terms of examining the information learned in this unit in the context of practical applications of sound, such as:

- production of music in string, wind, and percussion instruments;
- speaking and hearing;
- hazards of sound pollution;
- soundproofing or insulation materials;
- echoes and reverberation in the construction of music rooms, auditoriums, and gymnasiums;
- mufflers on automobiles;
- ranges of frequencies in the design of loudspeakers;
- sonar and its uses;
- ultrasonic phenomena.

UNIT S22: VIRUSES, MONERANS, AND PROTISTS

If this optional unit is selected as part of the program, only those topics that are marked with an asterisk (*) are mandatory. The remaining topics are suggested, but are optional.

The suggested time frame is applicable only for those situations in which the teacher plans to teach every topic within the unit.

Topics	Number of Periods
S22.1 *Viruses	2
S22.2 *Monerans	1
S22.3 Cyanophytes	2
S22.4 *Structure and action of bacteria	2
S22.5 *Importance of bacteria	3
S22.6 Bacteria in the laboratory	2
S22.7 *Microbes and disease	3
S22.8 *Protists	4
Review and evaluation	2
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Preamble

In this unit, students will extend their understanding of the diversity among living organisms. This unit will build upon the background gained in such units as Classification of Living Things (Unit E2), Life Cycles (Unit E11), Plants (Unit E15), and Fungi and Simple Plants (Unit S13). Students will focus their observations on both the similarities and the differences among organisms, and perhaps reflect upon the possible reasons for these. Some teachers may wish to analyse the nature of classification schemes, starting with the two-kingdom system and proceeding to the five-kingdom scheme proposed by Whittaker in 1969. In this last classification system, all organisms can be classified into the following kingdoms:

- moneran (bacteria, blue-green algae)
- protist (simple algae, protozoa)
- fungi
- plant (complex algae, mosses, ferns, seed plants)
- animal

This unit provides an opportunity for students to extend their laboratory skills – manipulating the microscope, preparing microscope slides, culturing micro-organisms, and conducting controlled experiments. In addition, cognitive skills of analysis and classification will be developed. Concepts such as cell structure and function, reproduction, life cycles, and development are emphasized.

Throughout this study, the concepts of simple/complex or primitive/advanced will arise. Students should realize that natural selection has been working on all organisms for a long time, and that the criteria of selection are survival and the ability to leave descendants. Some organisms might have evolved from a complex to a simple state; for example, some parasites can survive without some of the functions that their host performs for them.

S22.1: Viruses

Are viruses living or non-living? The answer will depend on the minimum criteria that are accepted as a definition of life: viruses have only the function of directing their own reproduction using the machinery of a host cell. Are they on the way to becoming living things, or are they parasites that have stripped away all non-essentials? Which way they are crossing the threshold of life is not clear. Students could study the structure and properties of viruses and learn how they interfere in the lives of the cells of living organisms. The reproductive mechanism of the bacteriophage could be elaborated. Photo-micrographs, overhead transparencies, and films could be very useful in complementing the teaching of this topic.

Suggested terminology: *virus, bacteriophage*.

S22.2: Monerans

The students should learn that the kingdom of monera includes the earliest organisms known to have lived on the earth. Some fossils resembling modern monerans have been found in Northern Ontario in the Gunflint chert formation near Schreiber. The following represents the kinds of additional information that students should have:

- Monerans are also very widely distributed, occurring in almost every known habitat.
- All are single-celled, with cells occurring either alone, in colonies, or in a network (mycelium).
- All of their cells lack a true nucleus, and the nuclear material (DNA) is dispersed throughout the cell. In effect, they lack the inner membranes that surround organelles in more advanced cells. Thus, monerans have no mitochondria or plastids.
- The cell walls are rigid, with a distinct chemical composition – they contain unique complex substances that do not occur in any other forms of life.
- Often the cells secrete a slime coating.
- Sexual reproduction is unknown to occur in most monerans, and reproduction occurs by simple fission.
- Many have the ability to form spores to resist extremes of temperature or dryness. There are two phyla, schizophyta (bacteria) and cyanophyta (blue-green algae).

Suggested terminology: *moneran, colony, mycelium, membrane, mitochondria, plastids, fission*.

S22.3: Cyanophytes

Students should prepare wet mounts of algae found on the bark of trees, on wet rocks, on flower pots, in earth, in bird baths, and on the inside of aquarium glass. Many of these will contain such blue-green algae as *nostoc*, *oscillatoria*, and *gleocapsa*. These monerans resemble bacteria in the characteristics listed in Topic S22.2, but differ from them in having chlorophyll, and thus being autophytes. Many have other pigments – blue, red, or brown – that may mask the green. They may occur singly or in filaments or colonies.

Students should learn that “algae” is a word from older classification schemes that meant “pond scums or sea weeds”. Today, the phyla of algae are differentiated into three kingdoms. It may be interesting for students to investigate some of the theories of the early development of life and of the relationship of the coming of the blue-green algae to changes in the atmosphere. The build-up of oxygen from photosynthesis is believed to have been made possible by the evolution of animal-like protists and, later, animals. Ecological relationships of blue-green algae and their environments could be studied. Is the concentration of certain kinds of algae in an area dependent on the environment? How does algal growth relate to the data collected from stream analysis?

Suggested terminology: *autophyte*, *autotrophic*, *protist*.

S22.4: Structure and action of bacteria

Students can further their understanding of bacteria with respect to the following points: relative size, basic shapes, general structure, movement, locomotion, conditions for growth, nutrition, reproduction. Audio-visual materials may enhance the teaching of this topic.

Suggested terminology: *coccus*, *bacillus*, *spirillum*, *capsule*, *flagellum*, *cytoplasm*, *heterotrophic*, *autotrophic*, *chemotrophic*, *aerobic*, *anaerobic*, *fermentation*.

S22.5: Importance of bacteria

A consideration of the distribution of bacteria and their rate of reproduction should leave the student with an awareness of their role in ecology as decomposers, symbionts, and parasites. Some of these roles may be illustrated with respect to their relationship to human life:

- The majority of bacteria have no direct relation to our lives or to our economy.
- Bacteria surround us at all times, and some live within our bodies.
- Even within our intestines, some bacteria are neutral, some provide us with vitamins, while some may make us ill.
- We can frequently use bacterial action or products for human gain, as in the processing of foods or industrial substances.

Students can investigate, either singly or in groups, such projects as vinegar-making, sauerkraut-making, the tanning of leather, the making of silage, the production of vitamin B-12, the retting of flax, the curing of tobacco, and the making of butter, buttermilk, yogurt, and cheese. Such in-class study could be complemented by visits to local industries or by visits from guest speakers. A worth-while addition to the topic might be the sampling of different cheeses.

Students should also be aware of the ways by which we try to prevent bacteria from competing for our food substances. In a general way, they should know how, when, and why these ways of preserving foods are used: canning, salt-curing, refrigeration, pasteurization, dehydration, quick-freezing, radiation, and the use of chemicals.

Suggested terminology: *spoilage*, *plasmolysis*, *enzyme*, *dehydration*, *radiation*.

S22.6: Bacteria in the laboratory

The following points should be very seriously considered before this topic is selected:

- safety and hazards (Some micro-organisms may be pathogenic.)
- background knowledge (Are teacher and students well prepared in the special techniques required?)
- equipment and supplies (Will these be available?)
- time (How long are we prepared to spend?)

Students could develop the following microbiological techniques and laboratory skills:

- growing of bacterial cultures – preparation, sterilization, inoculation, and incubation;
- preparation of slides of bacteria, staining;
- use of the high-powered and oil-immersion lenses of the microscope;
- isolation of pure strains of bacteria;
- identification and study of different bacteria.

S22.7: Microbes and disease

Students should know that some viruses, bacteria, protists, and fungi are capable of causing disease, and that the disease may be the result of either the damage to cells by the growth of the parasite or by the production of toxin. They should become aware that these agents cause disease in a wide variety of organisms, including humans. Students should learn about some common human, plant, and animal diseases; the agents responsible; the effects; and the control measures.

Suggested terminology: *pathogen*, *leucocyte*, *pus*, *antibody*, *antigen*, *immunity*, *vaccination*, *antibiotic*, *resistance*, *carrier*, *infection*.

S22.8: Protists

Students could begin this study by examining samples of water from ponds, streams, ditches, moist earth, and hay infusions. They should prepare wet mounts of pond scum and other samples and should sketch the structure of the algae and protozoa encountered. Identification keys could be used to develop the skills of analysis and classification. Purchased cultures, prepared microscope slides, and audio-visual materials could be made available to augment the studies of free-living specimens. The skills of biological drawing from specimens could be developed.

The organisms of the kingdom protista include aquatic single cells and colonies of many similar cells without differentiation of tissues. All have true nuclei and mitochondria. Some have several nuclei and are considered to be acellular. Most reproduce sexually by conjugation. There are two subkingdoms, the algae and the protozoa.

Algae in this group possess chlorophyll in membrane-bound chloroplasts and are autotrophic. Some examples are euglena (which swim with the aid of flagella), dinoflagellates, diatoms, and vau-cheria.

Protozoans lack chlorophyll and move in search of food, which they either engulf or dissolve externally and absorb by diffusion.

Students should realize that protozoa cannot be assumed to be simple organisms, that they depend on specialized organelles for the performance of their life activities, and that they inhabit almost every imaginable kind of environment. Students could consider size and distribution, the nature and structure of the cell, types of nutrition, locomotion, reproduction, and sensitivity to environment.

Suggested terminology: *mitochondria, nucleus, nucleolus, vacuole, flagellum, cilia, pseudopod, chloroplast, fission, conjugation.*

Part D: Appendices

Ontario Ministry of Natural Resources



Studbury Star Photo



APPENDIX A: THE USE OF SI METRIC UNITS

Policy: To adopt SI

It is policy that measured quantities be expressed in SI units or in units that are permitted for use with SI. Teachers must, therefore, become so familiar with SI units that they can use them quite naturally. For adults who have become thoroughly used to the imperial system of units, this requires a certain amount of deliberate practice. Almost unconsciously, we think of a tadpole with a one-inch tail; of a car travelling at 30 m.p.h.; of lowering the objective of a microscope until it is about a quarter of an inch above the stage; or of the sun's being 93 000 000 miles away. To set a good example and to reinforce the learning experience of the students, these references should quite naturally be expressed as a 2.5 cm tail; a speed of 50 km/h; 6 mm above the stage; and 150 000 000 km away.

This appendix outlines some of the measurement quantities that will be used in the Intermediate Division science program. In many units of study, there is some quantitative aspect that must be expressed metrically. Even in a qualitative investigation, students may ask how much water they should pour into the test tube or how long a piece of string they should cut. Such questions should be answered in metric units.

Teachers will find an increasing familiarity among their students with SI units and their symbols. It is not difficult for adults to use metric units consistently, even if they have been used to another system. The sooner metric units are fully adopted, the easier the change will be. Metric conversion should be accepted, and even welcomed, with a positive and enthusiastic attitude. Although science teachers have been using the metric system, they will find that SI is bringing a number of significant changes in the teaching of science. Teachers are urged to use the accepted and preferred metric units whenever units of measure are involved.

Concept of consistency

It is important to point out that there is only one SI unit of length and that unit is the metre. All other so-called units are, for convenience, expressed as multiples or submultiples of the metre. A thousand metres and a kilometre are the same length, and kilo is really the expression of a number. There is, therefore, no new unit introduced when we talk

of a kilometre; it is simply 1000 m. Similarly, a centimetre is just a suitable submultiple of a metre; its name means 0.01 m. In all SI expressions of length, the metre plays a unique role: it's always there to express length. The prefixes are merely numbers that we attach to this single unique unit of length.

SI is said to be *consistent*: this means that there is a single unit of length, a single unit of temperature, a single unit of force, and so on. As soon as a rule is stated, exceptions come to mind. One may ask about other units of length that are in vogue. None of them belong to SI (apart from the prefixed multiples and submultiples), but a few selected ones are permitted for use with SI. The exceptions are generally restricted to specialized fields or they are permitted because of their universal convenience and acceptance. The nautical mile (exactly 1852 m) is permitted for navigation. The second is the SI unit of time, but the minute (exactly 60 s) is accepted the world over; although it is a non-metric unit, it is permitted for use with SI.

The distinction between SI and non-SI units is probably not important to most students, but it is convenient to know that SI is consistent and to recognize that there is a single unit used in SI to measure each physical quantity: metre for length, second for time, newton for force, joule for energy, and so on. For the purposes of this appendix, we shall call such a unit the "primary" unit of length, or time, or whatever it is that we are measuring.

In contrast to SI, the imperial system is not consistent. For example, it has no single unit of length, such as the foot, with multiples and submultiples such as a decifoot, hectofoot, and so on. If the yard were called a "trifoot", the fathom a "hexafoot", and the rod a "sixteenandahalfafoot", then it might be argued that the imperial system is consistent. However, such is not the case.

Length

The metre is the primary unit of length in SI. Its multiples (such as the decametre, hectometre, kilometre, and megametre) and its submultiples (such as the decimetre, centimetre, millimetre, and micrometre) are formed by attaching a prefix and are secondary units of length.

Students should understand the meanings of the prefixes, but very little emphasis should be given to "hecto", "deca", "deci", and "centi", except for "hecto" in "hectare" and "centi" in "centimetre". The decimetre is a useful unit for teaching purposes and for the odd practical application.

In Intermediate Division science, the important units of length are the kilometre (km), metre (m), decimetre (dm), centimetre (cm), and millimetre (mm), and, for work with microscopes, the micrometre (μm). *Note: the micron (μ) is now obsolete.*

Dimensions of electron-microscope specimens are often given in nanometres (nm). Passing reference may perhaps be made to the megametre (Mm) and the gigametre (Gm) in earth and space science.

The millimetre will be very common in technology and engineering, in construction, and in the hardware business. The centimetre will be predominant in the clothing and textile sectors and in body measurement. It will be used frequently in biology. The decimetre is used on the sides of ships to indicate their depth below the water line, and peat moss is now sold in bales marked in so many cubic decimetres (dm^3) or litres (L). The cubic decimetre is equivalent to the litre and will be useful in studies on density. Teachers should be quick to observe applications of metric units and to use such examples to enrich the teaching of science.

Metric conversions

Impractical conversions between metric units should be avoided. It is a waste of time to have students convert 29.2 mm to hectometres. This kind of exercise is tedious and unnecessary, although relatively simple. Such problems are sometimes seen in the classroom – change 15 daL to millilitres, or 290 cg to hectograms; they do not belong in the curriculum, because they do not belong anywhere else. Time should be spent on useful and more probable applications. Frequently, a given length must be converted to metres before it can be substituted in a formula; this kind of conversion makes sense. Other examples of conversion problems within the metric system should be related, where possible, to practical applications.

Choice of prefix

The reason for converting from one unit to another is sometimes based on the need to use a more suitable multiple or submultiple. In some instances it is difficult to choose an appropriate prefix. How should the distance from the earth to the sun (150 000 000 km) be expressed? It is generally desirable to keep numerical values in the range from 0.1 to 1000 if convenient, or possibly up to 10 000 if there is a good reason. Numbers much higher become difficult to conceive. Thus, 25 500 m is simply expressed as 25.5 km. However, for comparison purposes, it is often necessary to permit numbers to fall outside the preferred range. If a distance in the solar system is to be compared with one on the earth, the kilometre would probably be chosen (compare the distance of 150 000 000 km from the earth to the sun with the 40 000 km circumference of the earth). On the other hand, if only solar distances are to be compared, a different prefix will reduce the numbers considerably (compare the earth's orbital radius of 150 Gm with Mercury's radius of 58 Gm).

Area

The primary SI unit of area is the square metre (m^2); all other units of area are secondary. The square hectometre (hm^2) is usually called by its non-SI name, the hectare (ha), which is permitted for use with SI. It is useful in stating population densities, as in 120 trees/ha. The quadrat frame should be a square metre. Areas of small surfaces such as those of leaves can be determined in square centimetres (cm^2). The square millimetre will not likely be used in science in the Intermediate Division.

Volume

The cubic metre (m^3) is the primary SI unit of volume; its non-SI name is the kilolitre (kL). Important submultiples of the cubic metre are the cubic decimetre (dm^3) and the cubic centimetre (cm^3), which use the non-SI names the litre (L) and the millilitre (mL) respectively. It is important to realize that these pairs of units are equivalent and interchangeable. The cubic decimetre and litre are exactly equal, but custom suggests that the cubic decimetre be used for volumes of solids and the litre for fluids. It is sometimes difficult to know when to use which unit. One brand of ice cream now comes in the shape of a decimetre cube; when frozen it is solid and has a volume of 1 dm^3 , but the label indicates the volume to be 1 L (the measurement when poured). The distinction between dry measure and fluid measure becomes redundant when the corresponding units have the same magnitude. In any event, students must consider the cubic metre and kilolitre to be equivalent, as are the cubic decimetre and litre, and the cubic centimetre and millilitre.



In Canada, the symbol for litre is now the upper-case "L". This applies also when there is a prefix, as in mL for millilitre. The lower-case "l" is recognized as the international symbol for litre and should be known as such by the students. However, because of the possible confusion between the numeral "1" for one and the letter "l" for litre, Canada has adopted the upper-case "L" as the symbol for the litre. The United States and Australia have also accepted the upper-case L. The script or cursive *ℓ* is to be gradually phased out.

Units in solutions to problems

In order to solve problems involving measurements, it is generally useful to include the units in the solution, as in the following examples:

- a) What is the area of a rectangle that measures 1.6 m by 85 cm?
 $A = lw = 1.6 \text{ m} \times 85 \text{ cm} = 1.6 \text{ m} \times 0.85 \text{ m}$
 $= 1.36 \text{ m}^2 \doteq 1.4 \text{ m}^2$
- b) If a rectangular box has a volume of 10.01 L and is 1.3 m long and 11 cm wide, how deep is it?
 $V = 10.01 \text{ L} = 10.01 \text{ dm}^3$
 $l = 1.3 \text{ m} = 13 \text{ dm}$
 $w = 11 \text{ cm} = 1.1 \text{ dm}$
 $V = lwh$
Hence, $10.01 \text{ dm}^3 = 13 \text{ dm} \times 1.1 \text{ dm} \times h$
and $h = \frac{10.01 \text{ dm}^3}{13 \text{ dm} \times 1.1 \text{ dm}} = 0.70 \text{ dm} = 7.0 \text{ cm}$
Here, the units must be matched, and the decimetre was chosen. The centimetre would work equally well using $V = 10\,010 \text{ cm}^3$, $l = 130 \text{ cm}$, and $w = 11 \text{ cm}$.

Mass

The kilogram is the primary SI unit of mass – the only SI base unit with a prefix. The submultiples gram and milligram should be familiar to students. Although they will not measure to the nearest milligram, they should know that this unit is often used in pharmaceuticals and in listing nutrients on cereal boxes. The megagram (Mg) is often called by its non-SI name, the tonne or metric ton. For larger masses the kilotonne (kt) or megatonne (Mt) may be used.

It is recommended that the use of the ambiguous word "weight" be avoided. In science courses, students will readily understand what is meant if teachers refer to mass when mass is meant and force of gravity when force of gravity is meant.

The gram-force and kilogram-force of former metric systems are not to be used in conjunction with SI.

The fact that a litre of water has a mass of 1 kg should be well known by students. It is not important to them that there is a slight discrepancy of a few parts per million in this statement.

It is recommended that students measure the mass of an object by means of a lever-type balance. They should understand that the mass of the object

is counterbalanced by a series of known masses (teachers should avoid calling them weights). Students will gradually realize that the force of gravity is equal on both sides of the balance. Through the use of a newton spring scale, students will come to realize that the force of gravity is proportional to the mass. When this concept is firmly established, students can then measure masses with spring scales, if desired. Such scales would be calibrated in grams and/or kilograms and are acceptable for measuring mass to the degree of accuracy demanded of students in the Intermediate Division. To state that spring scales cannot be used to measure mass is misleading, but students should know that such scales have limitations and should not, for instance, be used on the moon unless they are recalibrated. Bathroom scales, used for measuring mass, should be graduated in kilograms. If such scales show readings in newtons, they should be used to measure only forces, not masses.

Time

In SI, the only unit of time is the second, along with its prefixed multiples and submultiples, such as the kilosecond (ks), millisecond (ms), and microsecond (μs). In science, this restriction is quite natural, but for everyday life it is not. In SI, this is recognized by permitting the use of non-metric units such as the minute (min), hour (h), day (d), and year (a – for annum). The SI purist or addict should be restricted to four "birthdays", namely when he or she becomes 1 s, 1 ks, 1 Ms, and 1 Gs old. While this recommendation is facetious, it can be useful to illustrate the exponential increase in a sequence of prefixes or powers of ten. For instance, how old would a person be at each integral power of 10 s?

10^0 s – only one second old; very, very young.

10^1 s – one decasecond old; very young.

10^2 s – one hectosecond old; just over a minute and a half.

10^3 s – one kilosecond old; just over a quarter of an hour.

10^4 s – not quite three hours old.

10^5 s – a little over one day old.

10^6 s – one megasecond old; almost twelve days old.

10^7 s – almost four months old.

10^8 s – three years and two months old.

10^9 s – one gigasecond old; almost thirty-two years old.

10^{10} s – over three centuries old.

This type of exponential increase may be somewhat analogous to such phenomena as population growths of bacteria.

In general, when metric units are preceded by numerals, the use of their symbols is strongly recommended. However, when non-SI time units are used in sentences, it may sometimes be more sensible to use the full word rather than the symbol, and this is permitted. For example:

- This year, February has 28 days.
- The life span of humans is about 70 years.
- Lavoisier died 14 years later (not 14 a later).

Temperature

The SI unit of temperature is the kelvin (K) and such units as the millikelvin (mK) and the kilokelvin (kK) are related to it. However, all of these are unnecessary in the Intermediate Division. A temperature change of one kelvin is the same as a change of one degree Celsius. It is recommended that all temperatures and temperature intervals in the Intermediate Division be stated in degrees Celsius, not in kelvins. The degree Celsius ($^{\circ}\text{C}$) is permitted for use with SI and is the unit for both temperature and change in temperature. The Celsius degree or former centigrade degree ($^{\circ}\text{C}$) is now obsolete. Prefixes are not used with degree Celsius. Students should know such temperatures as the freezing and boiling points of water and normal body temperature.

Speed

The primary SI unit of speed is the metre per second (m/s or $\text{m}\cdot\text{s}^{-1}$). A speed of 1 m/s is generally demonstrated by students moving from one class to another – more or less. Submultiples of the metre per second, such as the centimetre per second (cm/s), are often useful. In addition, such units as the metre per minute or the kilometre per hour are also permitted. Some students may wish to compare the speed of an object, as measured in metres per second in the science room, with that of a familiar traffic speed. For example: Which has the greater speed, a trolley moving at 12 m/s or a car moving at 50 km/h ? This may be done as follows:

- Method (a):

$$12 \text{ m/s} = \frac{12 \text{ m}}{1 \text{ s}} \times \frac{1 \text{ km}}{1000 \text{ m}} \times \frac{3600 \text{ s}}{1 \text{ h}} = 43.2 \text{ km/h}$$

Hence, $12 \text{ m/s} < 50 \text{ km/h}$.

- Method (b):

$$50 \text{ km/h} = \frac{50 \text{ km}}{1 \text{ h}} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ h}}{3600 \text{ s}} \doteq 14 \text{ m/s}$$

Hence, $50 \text{ km/h} > 12 \text{ m/s}$.

Students may be interested in contributing to a chart showing the range of speeds of various items from the amazing rapidity of light ($3 \times 10^8 \text{ m/s}$) to the imperceptible slowness of a glacier (about 1 m/a or $3 \times 10^{-8} \text{ m/s}$). Such a chart could include the speeds of animals, vehicles, athletes, aircraft, space modules, rate of growth of plants, and so on.

Density

The SI unit of density is the kilogram per cubic metre (kg/m^3 or $\text{kg}\cdot\text{m}^{-3}$). This is a much smaller unit than the former commonly used unit, the gram per cubic centimetre. Therefore, the numbers involved in stating densities in kilograms per cubic metre must be much larger than those to which we have been accustomed. In SI, the density of water is stated as 1000 kg/m^3 or 1000 g/dm^3 .

When a value is substituted for density in a formula, it is much better to use the SI primary unit for density – the kilogram per cubic metre – rather than some other unit. This is because all the primary units “match” one another in the way that they are derived from the seven base units of SI. Thus, in the formula $p = Dgh$, for the pressure at depth (h) in a liquid, if the density (D) is in kilograms per cubic metre, the acceleration due to gravity (g) is in metres per second squared, and the depth is in metres (as would be expected in SI), then the pressure (p) will “automatically” be in pascals. Incidentally, here, the gravity-mass ratio (g) in newtons per kilogram could be used to advantage.

The product or quotient of primary units always gives another primary unit without any numerical conversion. This property of coherency is the strength of SI. It may be illustrated again with the following example, although the formula will not be used in the Intermediate Division. The speed of a compression wave through a solid is given by the formula $v = \sqrt{E/D}$, where E denotes Young’s modulus and D the density of the material. If E is expressed in pascals and D in kilograms per cubic metre, then the value of the speed (v) will “automatically” be in metres per second.



These formulas, $p = Dgh$ and $v = \sqrt{E/D}$, are not likely to be used in Intermediate Division science, but they illustrate the fact that teachers require a rationale for selecting the most appropriate unit for density. If the densities were expressed in grams per cubic centimetre and such values substituted in these and similar formulas, students would be burdened with comparatively complex problems in unit analysis. In general, then, it is recommended that densities be given in kilograms per cubic metre when using SI, particularly for students who plan to take further courses in science.

The cubic metre is too large a volume to use in the conceptual thinking of the density of a substance. However, the kilogram per cubic metre is equivalent to the gram per litre or the gram per cubic decimetre. It is, therefore, suggested that in the laboratory densities be determined in either of these equivalent units and then changed to the primary SI unit of density by merely changing the symbols without changing the numerical value. Of course, students should realize why such a change is justified. The following examples illustrate this point:

- a) A student finds the mass of 200 mL of a liquid to be 166 g. What is the density of the liquid?

Method (i): 200 mL of the liquid has a mass of 166 g.

Therefore, 1000 mL or 1 L of the liquid has a mass of 5×166 g or 830 g. That is, the density of the liquid is $830 \text{ g/L} = 830 \text{ kg/m}^3$.

Method (ii): $V = 200 \text{ mL} = 0.2 \text{ L}$, $m = 166 \text{ g}$

$$D = m/V = \frac{166 \text{ g}}{0.2 \text{ L}} = 830 \text{ g/L} = 830 \text{ kg/m}^3$$

- b) A 330 g stone displaces 83 mL of water. What is the stone's density?

Method (i): $m = 330 \text{ g}$, $V = 83 \text{ mL} = 0.083 \text{ L}$

$$D = m/V = \frac{330 \text{ g}}{0.083 \text{ L}} = 3976 \text{ g/L}$$

$$\doteq 4.0 \times 10^3 \text{ kg/m}^3$$

Method (ii): $m = 330 \text{ g}$, $V = 83 \text{ mL} = 83 \text{ cm}^3$

$$D = m/V = \frac{330 \text{ g}}{83 \text{ cm}^3} = \frac{330 \text{ g}}{83 \text{ cm}^3} \times \frac{1000 \text{ cm}^3}{1 \text{ dm}^3}$$

$$= 3976 \text{ g/dm}^3 \doteq 4.0 \times 10^3 \text{ kg/m}^3$$

It is not necessary to insist that all students express densities in the preferred SI unit, the kilogram per cubic metre. Some students who will not go on with further studies involving density may find it sufficient to work only in terms of the gram per litre.

It would be advantageous to have a cubic metre frame in the science room. It may be attached to hooks in the ceiling so that it can be taken down when required. If a cubic decimetre frame is also available, students can realize that if either cube were filled with a substance, the density would be the same regardless of the volume. It may also be pointed out that 1 m^3 of air has a mass of about

1 kg ; that 1 m^3 of water has a mass of 1000 kg or 1 t ; and that 1 m^3 of steel has a mass of nearly 8 t .

The term "specific gravity" has been replaced by the expression "relative density". For example, the relative density of aluminum

$$= \frac{\text{density of aluminum}}{\text{density of water}} = \frac{2700 \text{ kg/m}^3}{1000 \text{ kg/m}^3} = 2.7.$$



Force

In SI, forces are measured only in newtons. In the Intermediate Division, there is no need to complicate the concept of force by reference to mass times acceleration. A force is simply a pull or a push and can be easily measured by a newton spring scale. A newton may be thought of as the force required to support two golf balls or a single D-cell flashlight battery. There are multiples and submultiples of the newton, such as the kilonewton (kN) and millinewton (mN), but these will not be common in the science program. Students should have the opportunity to measure a good number of different kinds of forces.

It is recommended that horizontal forces (such as those involved in dragging blocks along the floor) and oblique forces (such as those involved in dragging blocks up a ramp) be measured first. Such forces depend on the types of surfaces involved and are difficult to estimate without repeated experience. Once students are used to measuring such forces, they can then consider the special case where a mass is supported against the pull of gravity. By lifting a number of different masses and measuring the required forces, students will find that it takes about 5 N to lift 0.5 kg , 10 N to lift 1 kg , 35 N to lift 3.5 kg , 50 N to lift 5 kg , and so on. This means that the force of gravity on these masses is 5 N , 10 N , 35 N , and 50 N respectively. The idea of the gravity-mass ratio of 10 N/kg can then be developed — the fact that over the surface of the earth, gravity exerts 10 N/kg on any object or substance. For most purposes, 10 N/kg is accurate enough; if greater accuracy is required, 9.8 N/kg or 9.81 N/kg may be used. It should also be explained that on the moon the gravity-mass ratio is only about 1.6 N/kg .

Knowledge of the gravity-mass ratio enables students to determine the force of gravity (teachers should avoid the use of "weight") acting on any known mass. For instance, if a girl knows that she has a mass of 55 kg, she should understand that the earth exerts a force of gravity of about 550 N on her in a downward direction. If she is to step up onto a chair, she must exert a force of about 550 N to do so. This is useful when determining the amount of work done or energy expended when doing some activity against the force of gravity.

Work and energy

In SI, work and energy are measured in joules (J). This applies to all forms of energy, whether mechanical, electric, thermal, chemical, or whatever. A joule is the amount of work done when a force of 1 N moves something through a distance of 1 m. The relationship between joules, newtons, and metres is simple: a 5 N force moving some object through a distance of 3 m requires 15 J of energy, or we can say that 15 J of work has been done. A newton metre is simply called a joule. (It should be realized that the distance travelled – or, strictly speaking, the displacement – and the force applied must be parallel.)

Students can do a number of activities and determine the amount of work done in joules. In some instances, the force can be measured with a newton spring scale, but in others, where the work is done against gravity, the force may be determined by measuring the mass of the object lifted and then applying the gravity-mass ratio of 10 N/kg. For example: How much energy is needed to raise a heavy man, having a mass of 100 kg, to the top of the CN Tower in Toronto, that is, to a height of 550 m?

$$\begin{aligned} m &= 100 \text{ kg}, g = 10 \text{ N/kg}, d = 550 \text{ m} \\ F &= mg = 100 \text{ kg} \times 10 \text{ N/kg} = 1000 \text{ N} \\ E &= Fd = 1000 \text{ N} \times 550 \text{ m} = 550\,000 \text{ N}\cdot\text{m} = 550\,000 \text{ J} \\ &= 550 \text{ kJ} \end{aligned}$$

Note: the use of the letter g for the gravity-mass ratio in the formula $F = mg$ agrees with Newton's second law and is equal to 10 N/kg or 10 m/s^2 by dimensional analysis. Hence, the use of g as the gravity-mass ratio in the Intermediate Division should reinforce the use of g as the acceleration due to gravity in the Senior Division, but there is no need to make any reference to acceleration in the Intermediate Division.

A common unit of energy, used in former metric systems, is the calorie. It is now obsolete and should not be used. In studies on heat, it may be shown that it takes about 4200 J to heat 1 kg of water through 1°C , and from this we can establish what is called the specific heat capacity of water as $4200 \text{ J}/(\text{kg}\cdot^\circ\text{C})$. If this value is to be established experimentally, the fact that a watt second is equivalent to a joule should be introduced first. The input energy can then be determined by knowing the wattage of an immersion heater and the number of seconds it takes to raise 1 kg of

water through a given number of degrees Celsius. The product of the watts times the seconds equals the number of joules of energy supplied.

The joule of energy is a small amount; therefore, the kilojoule (kJ), megajoule (MJ), and perhaps the gigajoule (GJ) will be commonly used. The Calorie (with a capital "C") used in diets is really a kilocalorie and is therefore equivalent to 4.2 kJ. The energy value of foods is of interest to students and some problems related to this topic may be given. It is expected that, for some time, electric energy will continue to be stated in kilowatt hours (kW.h) in industrial and consumer applications. It is hoped that eventually the megajoule will replace the kilowatt hour ($1 \text{ kW}\cdot\text{h} = 3.6 \text{ MJ}$).

Power

Power, the rate at which work is done or energy is transferred, is always stated in terms of watts in SI. $1 \text{ W} = 1 \text{ J/s}$. Students should have the opportunity to perform activities in which the work done can be measured and timed. The corresponding power can then be calculated and expressed in watts. A task may be carried out with the left arm and then with the right arm. A student may find out that he or she has a 55 W left arm and a 65 W right arm – indicating the power of each arm during the activity. Such mechanical power may be compared with the electric power required to operate a light bulb or appliance. Kilowatts (kW) and megawatts (MW) will be common and may be of interest to students, particularly if they can witness the operation of motors or engines with known kilowatt and megawatt ratings.

In electrical work, it may be desirable to point out that the watt is equivalent to a volt ampere, so that a 110 V circuit drawing 5 A is consuming energy at a rate of 550 W. It is important that students know that watts indicate the rate at which energy is used.



Pressure

The primary SI unit of pressure is the pascal (Pa), which is equal to a newton per square metre. A bundle of 100 one-dollar bills lying on a table exerts a force of about 1 N downwards on the table. If the dollar bills are spread out side by side, they cover an area of about 1 m². They then exert a force of 1 N over 1 m², that is, a pressure of 1 N/m² or 1 Pa. The pressure exerted by each dollar bill is also 1 Pa. What about a one-thousand dollar bill? 1 kPa? Some fall for this one!

Pressures are not to be given in terms of millimetres of mercury since this unit is now obsolete. Standard atmospheric pressure is 101.325 kPa (or roughly 100 kPa) and the air pressure in a car tire is about 200 kPa above standard atmospheric pressure. A pressure gauge measures only the gauge pressure, that above (or below) atmospheric pressure. The total pressure in the tire is about 300 kPa and is known as the “absolute pressure”. Students should know the difference between absolute and gauge pressure. The pascal is a very low pressure, so the kilopascal will be in common use.

Moment of force or torque

Moments of force or torques are measured in newton metres (N·m) in SI. A moment of force is the product of a force and a distance that are always perpendicular to each other, and this product is never equated to a number of joules, only to a number of newton metres. In activities involving the determination of moments of force, care should be taken to measure the forces in newtons, not in grams or kilograms. If masses are used to exert vertical forces, the gravity-mass ratio of 10 N/kg can be useful in determining such forces.

Frequency

In SI, the unit of frequency is no longer the cycle per second, but the hertz (Hz). This is equivalent to the cycle per second and is often called the reciprocal second, since $1 \text{ Hz} = 1 \text{ s}^{-1}$. In a problem, the symbols Hz and s^{-1} are interchangeable. For example, in acoustics, velocity (v) = $f\lambda$ = $256 \text{ Hz} \times 1.31 \text{ m} = 256 \text{ s}^{-1} \times 1.31 \text{ m} = 335 \text{ m/s}$ or $256 \text{ Hz} \times 1.31 \text{ m} = 1.31 \text{ m} \times 256/\text{s} = 335 \text{ m/s}$.

Structure of SI

The seven base units of SI are the metre, kilogram, second, kelvin, ampere, mole, and candela. We have stated that the SI primary units are these seven plus those units that are derived simply by multiplying and/or dividing these base units. A system of measurement constructed in such a manner is said to be *coherent*. The major advantage of a coherent system is that no conversion factors (other than the number one) are used to create the system. The joule, for example, is coherent; it is equal to exactly $1 \text{ kg}\cdot\text{m}^2\cdot\text{s}^{-2}$, a simple combination of base units. The calorie, however, is not coherent since it is equal to $4.19 \text{ kg}\cdot\text{m}^2\cdot\text{s}^{-2}$, which involves an awkward conversion factor to relate it to SI base units. Primary SI units, then, are preferred for most work in science, particularly when formulas are used.

Secondary units are those that we have defined as multiples or submultiples of the primary units and that are formed by means of prefixes. These are also members of SI and are useful in practical work.

Permitted units are exceptions to primary and secondary units. Some units are permitted for use with SI because they are universally popular and convenient, such as the minute, hour, and day. Others are permitted in specialized work, such as the nautical mile used in navigation. Still others are units that have been given familiar names, such as the litre, which is called the cubic decimetre in SI.

The chart at the end of this article indicates examples of units in the three categories: primary, secondary, and permitted.

The further a student advances in science, the more he or she will tend to use SI units, particularly the primary units. In the Intermediate Division, this transition from common everyday units to the set of coherent SI units is just beginning. Students should not be pushed too far too soon; they should be permitted to use common everyday units for many purposes. As they gradually master the equations of science and apply them to problem-solving, they will gradually see the advantage of converting given data to primary units and then substituting such values into the equations to obtain the unknown quantities expressed in their appropriate primary units. The following table contains many of the units that are likely to turn up in the Intermediate Division science program.

Primary, Secondary, and Permitted Units

Quantity	The Primary SI Unit	Some Secondary Units	Some Permitted Units
Length	metre (m)	kilometre (km) decimetre (dm) centimetre (cm) millimetre (mm)	nautical mile (n.mi.) astronomical unit (AU) parsec (pc)
Area	square metre (m ²)	square kilometre (km ²) square centimetre (cm ²)	hectare (ha)
Volume	cubic metre (m ³)	cubic decimetre (dm ³) cubic centimetre (cm ³)	litre (L) millilitre (mL)
Mass	kilogram (kg)	megagram (Mg) gram (g) milligram (mg)	tonne (t) or metric ton
Time	second (s)	millisecond (ms) microsecond (μs)	minute (min) hour (h) day (d) year (a)
Temperature	kelvin (K)	millikelvin (mK)	degree Celsius (°C)
Speed	metre per second (m/s)	centimetre per second (cm/s)	kilometre per hour (km/h)
Density	*kilogram per cubic metre (kg/m ³)	gram per cubic centimetre (g/cm ³)	*gram per litre (g/L)
Force	newton (N)	kilonewton (kN)	
Work, Energy	joule (J)	kilojoule (kJ) megajoule (MJ)	kilowatt hour (kW•h)
Power	watt (W)	kilowatt (kW) megawatt (MW)	
Pressure	pascal (Pa)	kilopascal (kPa)	
Moment of force	newton metre (N•m)	kilonewton metre (kN•m)	
Frequency	hertz (Hz)	kilohertz (kHz) megahertz (MHz)	1 Hz = 1 s ⁻¹

*1 kg/m³ = 1 g/dm³ = 1 g/L



APPENDIX B:

LABORATORY SAFETY

Introduction

In all science courses in the Intermediate Division, teachers should strive to instil in their students a positive attitude towards safety. An awareness of safety should be developed through a common-sense approach. Scare techniques must be avoided.

When conducting experiments, students should be expected to follow directions as given, to understand the import of what they are doing, to maintain order and neatness in arranging their equipment, to use prior knowledge in making judgments, and to ask for advice when in doubt.

Students must be impressed with the importance of following instructions exactly. If a concentrated acid is to be diluted, the acid must be added slowly to the water, not the water to the acid. This example illustrates the need to give complete and exact directions and to have them obeyed fully. It cannot be assumed that all students know of the corrosive power of acids and bases, of the poisonous effects of mercury or asbestos, of the danger of carbon tetrachloride fumes, of the explosive nature of certain gases, or of the hazards of handling some micro-organisms.

Scientific knowledge plays a vital role in laboratory safety. Students should often learn by experimenting, but such experimentation must be judiciously directed. No laboratory work should be expected of the students where they may not be fully aware of possible hazards and their prevention.

Teacher responsibility

The most effective method of teaching safety is by example. The techniques, procedures, and attitudes displayed by the teacher are likely to influence students more than actually teaching them a unit on safety. The teacher should be conscious of the example he or she exhibits towards safety and should encourage the development of the following traits or attitudes:

- careful observation and alertness at all times;
- constant application of safety techniques;
- constructive criticism of experimental procedures;
- recognition of the need for experimental design and the responsibilities associated with such design.

Teachers should practise effective surveillance of all students, with an emphasis on accident prevention. Students should be alerted to situations that they have created that could be unsafe or hazardous.

The following guidelines should be of assistance to teachers in avoiding and treating accidents and in manipulating apparatus:

- Teach and practise safety at all times.
- Practise the traits and attitudes expected of students.

- Never leave students in the laboratory unsupervised during a potentially dangerous experiment.
- Test all experiments before the students perform them.
- Caution students and alert them to potential hazards before they attempt an experiment.
- Do not permit any form of "horseplay" in the laboratory.
- Establish a routine of having students make a safety check of apparatus before using it in an experiment.
- Before using a chemical, use your knowledge of it to determine the safe storage, handling, and transporting procedures for it.
- Provide safety equipment for individual student use: for example, protective eyewear. Inspect it and keep it in good repair.
- Inspect storage areas frequently to eliminate potential hazards.
- Before performing experiments, have the laboratory or classroom equipped with the proper safety equipment, for example, complete first-aid kit, fire blanket, fire extinguishers, fire pail, and sand.
- Make sure students know how to use safety equipment.
- Be familiar with current first-aid treatment, such as that for the treatment of burns.
- Be familiar with the routine to follow in your school in case of an accident. Be aware of who else may be called upon for assistance with first aid in the school.
- On the first appropriate day, instruct students on what to do if chemicals get in their eyes.
- Frequently inspect laboratory and classroom facilities, such as gas fixtures, electric outlets and connections, fume hoods, and exhaust fans. Have them repaired if defective.
- Ensure that students are properly supervised when handling dangerous substances.
- Do not perform or have students perform any experiments that could produce a hazard for which you as the teacher could not provide first aid.
- Emphasize conducting experiments in logical, organized steps, avoiding unnecessary movement or crowding in the classroom.
- Do not use any new products or untried substitutes without having the benefit of testing to determine possible limitations or hazards.
- Encourage students to carry out safety procedures without making them afraid to experiment.
- Have available for immediate reference when needed information on safety and first aid.
- Stress the importance of special care when handling glass tubing. (See the section on glass tubing below.)

Student responsibility

At the beginning of each year, students should be alerted to general safety precautions. To guarantee continuing safety, students should become familiar with the condition and safety features of all equipment and chemicals used. They should plan their laboratory exercises and experiments to minimize the possibility of accidents. They should record and investigate with the teacher any accidents or unexpected events that occur.

Students *should*:

- be familiar with the location and use of safety equipment in the classroom or laboratory;
- report all accidents to the teacher at once no matter how minor;
- wear safety equipment such as protective eyewear when required (if contact lenses are worn, they should be removed immediately if a foreign body or liquid enters the eye);
- report broken equipment, damaged or defective facilities, and suspicious-looking chemicals to the teacher;
- wash up after working with preserved specimens, micro-organisms, or poisonous materials;

- practise safety inside and outside of the classroom;
- maintain an uncluttered work area.

Students *should not*:

- wear loose clothing near flames or permit long hair to come near open flames (loose clothing and long hair must be tied back);
- conduct experiments without proper supervision;
- handle apparatus, chemicals, live animal specimens, or poisonous plants without specific previous instructions;
- transport dangerous materials at any time without full knowledge of and adherence to safety precautions;
- handle any material in the classroom, laboratory, or storage room without permission;
- taste chemicals or other materials without specific instructions and supervision by the teacher;
- remove glass tubing from, or insert it into, rubber stoppers without teacher supervision;
- leave a lighted burner unattended (burners should be extinguished or shut off when not being used).



Safety in using glass tubing

Instructions such as the following should be available to students who are expected to use glass tubing. Such directions should be reviewed in advance.

Storage. Glass tubing should be stored horizontally and supported the full length of the tubing.

Cutting. Small-diameter glass tubing may be cut by first marking the glass with a triangular file or a glass cutter. For large-diameter tubing, use a cutter.

After marking the glass tubing, do not attempt to break the tubing without wearing protective equipment for the hands and eyes. This means the wearing of gloves and goggles; if you do not have gloves, wrap the tubing in paper or cloth around the place to be cut and for about a decimetre on either side. Hold the tubing with the mark directly in front of you and with your thumbs behind the tubing; press towards the mark, with your thumbs pushing forward while your fingers pull towards you. This should give a clean sharp edge.

Fire-polishing. All glass tubing should be fire-polished to remove sharp edges. This is accomplished by rotating the end of the tube in the edge of the flame of a Bunsen burner until the end becomes yellow or orange. Be careful not to change the bore size of the tubing by overheating. *Caution:* Do not handle glass that has been heated until you have allowed time for cooling. Attempting to speed up the cooling by placing the glass in cold water will crack or shatter the glass.

Bending. Glass tubing may be bent by heating it at the point of bending in a Bunsen burner, while the glass is rotated slowly. Apply pressure to obtain the amount of bend desired when the glass becomes pliable. *Caution:* Do not overheat and thus change the size of the bore. You cannot see the heat in glass tubing; allow plenty of time for cooling before you handle the glass.

Inserting glass tubing into rubber stoppers or tubing. Always fire-polish or smooth the ends of glass tubing with a file or emery cloth before attempting to insert glass tubing into a rubber stopper. Apply water or soap as a lubricant and put the tube into the stopper with a screwing motion. Wear protective equipment for the hands and eyes. Aim the glass tubing away from the palm of the hand when holding the stopper or rubber tubing. Grasp the glass tubing as close to the rubber stopper as possible and "feed" it slowly into the stopper. Commercial glass-tubing manipulators such as "Grip-Safe" are available from some supply houses and are useful for inserting or removing glass tubing.

Removing glass tubing from rubber stoppers. Remove glass tubing as soon as possible after use to prevent the glass from "freezing" to the stopper. If the glass has frozen or the stopper has become hardened, it may be best to split the stopper with a sharp knife. Wear protective equipment for the hands and eyes when removing glass tubing from rubber stoppers. The tubing is removed in a manner similar to inserting; that is, by lubricating the glass and twisting the stopper gently while holding the tubing close to the stopper.

APPENDIX C: PLANT AND ANIMAL CARE

Introduction

If (a man) has been touched by the ethic of Reverence for Life, he injures and destroys life only under a necessity which he cannot avoid, and never from thoughtlessness. So far as he is a free man he uses every opportunity of tasting the blessedness of being able to assist life and avert from it suffering and destruction. Devoted as I was from boyhood to the protection of animal life, it is a special joy to me that the universal ethic of Reverence for Life shows that sympathy with animals, which is so often represented as sentimentality, to be a duty which no thinking man can escape.

Albert Schweitzer, 1949

Teachers of science have a responsibility to develop in their students a respect for life and an understanding of the conditions necessary for its perpetuation. To this end, living organisms should be available to be studied and cared for by students. Students should learn their responsibilities towards living organisms and should be involved in their care and maintenance. They should take pride in their ability to maintain animals and plants in a healthy state and in a proper environment for which they, the students, are responsible. Today's emphasis on the environment makes it imperative that students experience the environmental necessities for maintaining life. The principles of animal care related to such variables as nutrition, cleanliness, space, exercise, and temperature can be compared to the principles governing the maintenance of human life with dignity in a proper environment.

The Animals for Research Act and Ontario schools

The Ontario Animals for Research Act is legislation that deals with animal care. When it was passed, it was the first comprehensive legislation providing for the comfort and well-being of all vertebrate animals in research. "Vertebrate" includes birds, fish, turtles, salamanders, and snakes, as well as such other common classroom residents as mice, rats, and guinea pigs.

"Research" is defined in the act as "the use of animals in connection with studies, investigation and teaching in any field of knowledge". This is a broad definition; hence, the Veterinary Services Branch, Ministry of Agriculture and Food, is concerned not only with the use of animals in university, industrial, diagnostic, and institutional laboratories, but also with the use of animals for teaching in primary and secondary schools and

with the experimental use of animals at science fairs. In the same way, the term "research facility" is a comprehensive one and every establishment, however small or large, that uses animals for studies, investigation, and teaching comes under the jurisdiction of the legislation.

Ontario schools have been exempt from registration as research facilities under the act, as well as from some of the regulations concerning room construction and procurement of animals; however, all other relevant portions of the act and its regulations apply to school and home animal projects.

The Animals for Research Act requires that every research facility or school that has or uses live animals during the school year come under the jurisdiction of an "animal care committee". The animal care committee is a peer committee. It may be made up of any number of persons. The qualifications of the animal care committee members are not specified, with the exception that one of its members must be a veterinarian. Animal care committees may be composed of teachers, consultants, supervisors, and persons outside the education system such as lawyers and animal care technicians.

A local animal care committee is appointed by one or more school boards. The animal care committee is responsible to the public through the Veterinary Services Branch; thus, a peer-government control system is being developed.

The initial task of the animal care committees will be to assemble to review and approve animal-project proposals in the schools and by the students under their jurisdiction. The animal care committee has the initial responsibility in the enforcement of the "pain clause" and may order that any project cease or not be proceeded with.

Animal care committees will control the character of animal utilization in schools in their area. It is expected that animal care committees will develop a standard list of animal projects which teachers in their area can use without further red tape. Any teacher or student who wishes to deviate from the standard procedures would be required to submit a separate project proposal for approval.

The "pain clause" requires that no animal suffer unnecessary pain. A project that may be necessary in a university or college teaching situation may be totally unacceptable and unnecessary at the pre-university level. The regulations do not clarify, grade, or specify a measure for pain. It is the task of the local animal care committee to determine what is suitable in their community, their schools, their grades, and with their students. It is recommended that in order to determine whether a project is suitable and necessary consideration be given to the following:

- the age, background, and intelligence of the student, and the capacity of the student to benefit from the experience;
- the total group of activities of which the animal project is a part;



- the preparation of the student and the follow-up lessons;
- the scientific design and the merits of the project;
- the merits of an alternative use of non-sentient material or lower forms of living material;
- the competence of the teacher or supervisor in relation to the proposed project;
- the level of competent supervision by teachers or qualified persons in the related field.

Ideally, these facts are best determined at the local level by teaching peers and the community through the local animal care committee.

In addition, the animal care committee has responsibilities concerning the activities and procedures related to the care of animals, the standards of care and facilities for animals, and the training and qualifications of persons who are engaged in the care of animals in schools. The acceptance of these responsibilities should produce a nucleus of trained personnel, resource material, and local expertise that will be available to teachers on animal projects, animal care itself, and animal care equipment.

The act and its regulations touch on all aspects of animal care and use. The regulations are general in nature and, in most cases, refer to the health, welfare, and comfort of the animal. The regulations discuss light, ventilation, temperature control, feed and water, cage requirements, cage cleaning and care. Euthanasia procedures are restricted. Amphibians, reptiles, non-human primates, and dogs and cats receive further attention in special sections in cases where their needs are not fully met by the general regulations.

The enforcement of the act and its regulations is through the animal care committee, spot inspection of schools, investigation of complaints, and inspection of science fairs by veterinarians and animal health technicians.

The Animals for Research Act controls the use of animals in science fairs in Ontario. Its application in regional science fairs has indicated that the peer-government system of control can achieve desirable results at the pre-university level.

The aim of the act is not, as some people have feared, the abolition of the use of animals in schools, but rather the proper maintenance and use of animals that are in the schools or involved with school-related projects. Both teachers and students must be conscious of the fact that today's students have moral and legal responsibilities for animals in their future studies or work; this early experience with proper animal care, proper animal use, and legislation is a necessary part of education. The Animals for Research Act and its regulations are available from:

The Director
Veterinary Services Branch
Ministry of Agriculture and Food
Parliament Buildings
Queen's Park
Toronto, Ontario
M7A 1A3
(416) 965-5841

Guiding principles governing the use of animals

These guiding principles have been prepared by the Canadian Council on Animal Care. They are recommended for use by departments of education and school boards across Canada so that adequate safeguards exist to ensure the proper care and use of animals in experimentation in the classroom in the schools in their jurisdiction. *These guidelines are not for use by students preparing projects for exhibit in science fairs.* Students preparing projects for science fairs must adhere to the Youth Science Fair Regulations for Animal Experimentation.

Biological experimentation involving animals in the classroom is essential for an understanding of living processes. Such studies should lead to a respect for all living things. All aspects of the study must be within the comprehension and capabilities of the students undertaking the study.

Lower orders of life are preferable subjects for experimentation at the pre-university level. Bacteria, fungi, protozoa, and insects can reveal basic biological information; they should be used for experimentation wherever and whenever possible.

All students conducting projects involving *vertebrate animals* should adhere to the following guidelines:

- No experimental procedures shall be attempted on a vertebrate animal that would subject it to pain or distinct discomfort, or interfere with its health.
- Anesthetic agents must not be used.
- Surgery on vertebrate animals shall not be performed.
- Experimental procedures shall not involve the use of:
 1. micro-organisms that can cause diseases in man or animals;
 2. ionizing radiation;
 3. cancer-producing agents;
 4. chemicals at toxic levels;
 5. alcohol in any form;
 6. drugs that may produce pain;
 7. drugs known to produce adverse reactions or side effects, or capable of producing birth deformities.
- Experimental treatments shall not include electric shock, exercise until exhaustion, or other distressing stimuli.
- Behavioural studies shall use only reward (positive reinforcement) and no punishment in training programs.
- Food shall be palatable and of sufficient quantity and balance to maintain a good standard of nutrition. Animals shall not be allowed to go below the maintenance level of nutrition. *Clean drinking water shall be available at all times.* Containers for food and water must be of a design made specifically for that purpose.
- If egg embryos are subjected to experimental manipulations, the embryos must be destroyed humanely two days prior to hatching. If normal egg embryos are to be hatched, satisfactory humane considerations must be made for the disposal of the young birds.
- All experiments shall be carried out under the supervision of a competent science teacher. It shall be the responsibility of the qualified science teacher to ensure that students have the necessary understanding for the study to be undertaken.
- All experimental animals used in teaching programs must be properly cared for. Animal quarters shall be made comfortable by providing for sanitation, protection from the elements, and space for exercise. The living quarters shall have surfaces that may be easily cleaned, good ventilation and lighting, well-regulated temperatures, and cages of sufficient size to prevent overcrowding. Students must not be allowed to take animals home to carry out experimental studies. All studies involving animals must be carried out in a suitable area in the school. Animals must be protected from direct sunlight or other environmental factors that may disturb the well-being of the animal.

- Colonies and animal quarters shall be supervised by a science teacher experienced in animal care. The students and other animal care staff shall be trained and required to handle the animals gently and humanely.
- The use of animals must comply with existing local, provincial, or federal legislation.
- All animals must be disposed of in a humane manner. If euthanasia has to be carried out, an approved method must be used and carried out by an adult experienced in such techniques.
- The procurement and use of animals and birds must comply with the Migratory Birds Convention Act of Canada and the Endangered Species Act of Canada, as well as any existing provincial legislation concerned with wild animals and exotic species.

Information on the care and housing of individual species may be obtained from "The Care of Experimental Animals: A Guide for Canada", available from the Canadian Council on Animal Care, 151 Slater Street, Suite 1105, Ottawa, Ontario K1P 5H3.

Sudbury Star Photo



Animal experimentation in science fairs

Biological experimentation is essential for an understanding of living processes. Such studies should lead to a respect for all living things. Capable students anxious to pursue a career in biological sciences must receive the necessary encouragement and direction. *All aspects of a project must be within the comprehension and capabilities of the student undertaking the study.*

Lower orders, such as bacteria, fungi, protozoa, and insects, can reveal much basic biological information. If experiments are to be conducted on living subjects for science fair projects, only lower orders of life may be used.

Vertebrate animals are not to be used in experiments for projects for science fairs, with the following exceptions:

- observations of the normal living patterns of wild animals in the free living state or in zoological parks, gardens, or aquaria;
- observations of the normal living patterns of pets, fish, or domestic animals. No living animal shall be displayed in exhibits in science fairs.

Cells such as red blood cells, other tissue cells, plasma, or serum purchased or acquired from biological supply houses or research facilities may be used in science fair projects. Observational studies on chicken egg embryos may also be used in science fair projects. If normal egg embryos are to be hatched, satisfactory humane considerations must be made for the disposal of the chicks. If such arrangements cannot be made, then the chicken embryos must be destroyed on the nineteenth day of incubation. No eggs capable of hatching may be exhibited in science fairs.

All experiments shall be carried out under the supervision of a competent science teacher. It shall be the responsibility of this teacher to ensure that students have the necessary understanding for the study to be undertaken. Whenever possible, specifically qualified experts in the field shall be consulted. For information and the names of qualified experts write to:

Canadian Council on Animal Care
151 Slater Street, Suite 1105
Ottawa, Ontario
K1P 5H3

Youth Science Foundation
Animal Care Committee
151 Slater Street, Suite 302
Ottawa, Ontario
K1P 5H3

Suggestions regarding experiments involving animals

The following acceptable areas of animal experimentation at the pre-university level are offered to give guidance to youth science fair participants, biology teachers, and science fair directors.

- *Physiology.* Measure the normal physiological parameters, such as the respiratory rate, heart rate, temperature, quantity of food eaten, and the length of time dye-markers take to pass through the gastrointestinal tract and appear in the feces. Fecal output and urine production can be measured. As well, the amount of water supplied by a diet of greens can be compared to the amount of water an animal will normally imbibe, when the greens are used instead of the water.
- *Reproductive biology.* This may be studied with mice, hamsters, gerbils, or rats. The species may be observed under a variety of conditions. Studies may be repeated on the same animals because of the short gestation period. The animals may be treated in the following ways or modifications of these ways:
 1. Before breeding, a group of animals is gently handled and given kind treatment by the student each day. After breeding, the gentle handling continues.
 2. A second group of animals does not receive this gentle treatment, but is left to breed in the cages.
 3. Two groups of animals are placed in a darkened room and not allowed any light; one group is removed each day and handled and the other group is not.

Many variations of this kind may be carried out without causing any distress to the animal. The number of the young-born is observed and recorded. In the same way, the number of young that are weaned is observed. In addition, the study can also involve the habits of the animals with respect to such factors as the provision of proper bedding materials or nest boxes.

- *Maze studies.* Students may wish to discover factors that might definitely lengthen or shorten the time it takes for an animal to journey through a maze. Will it make any difference to vary the amount of gentle handling or to vary the type of environment in which the animal lives (modified as to darkness or light, soft music or rock music, cool at 18°C or warm at 28°C, and so on)? Only positive reinforcement should be used; negative influences such as electric shock, food deprivation, drastic temperature extremes, or painful prodding must not be permitted. With respect to

temperature, variations within three to six degrees Celsius below or above the recommended normal maintenance temperature for the animal should not be exceeded. For example, if the normal temperature for a rat is considered to be 22°C, it is not recommended that the effects of temperature below 18°C or above 28°C be studied.

- *Environmental studies.* Again, light, darkness, and temperature may be considered in relation to gains in mass, to food intake, or to urinary output in young animals. The animals can be maintained in the darkness, handled or not handled, and then be brought into the light and handled regularly. Temperature variations should not exceed those mentioned under maze studies. Increase or decrease in mass can be observed under each variable.
- *Nutritional studies.* Again, none of these studies should involve the production of deficiencies or disease in animals. However, many studies can be carried out in which animals eat a balanced diet in different forms: for example, one group may be given food in a cube state (recognizing that most rodents are gnawers), another group may be fed on a powdered ration or a meal mixture, and a third group may be given food that is moistened with water. The animals used should be in the growing stage. They should be weighed each day, and such measurements as gains in body mass recorded. In this way, students learn to handle the animals and to make reliable measurements. In such studies, fecal and urinary output are other possible variables that can be measured.
- *Behavioural studies.* The effect of enriched environments (as compared with environments in which only the necessities, such as food and water, are provided) on the behaviour of animals may be studied. Students may let their imaginations free to create such environments: such environments can utilize bright or dull colours, round or square objects, and so on. Many psychology departments conduct studies in which behavioural scientists look at the effects of enriching an environment. This has a positive application to contemporary problems of human sociology.
- *Anatomical preparations.* The bodies of dead animals may be obtained from humane societies or research laboratories where animals have been killed humanely. The preparation of skeletons from these animals by cleaning the bones and restructuring the body is a giant task. A comparison of the various bones in animals is another interesting study, particularly if the function of the bones is also considered.
- *Genetics.* Various colours of mice, rats, hamsters, or rabbits may be bred and the colour adaptations recorded. Similarly, one can study the effects of random breeding, brother and sister matings, and line breeding with respect to the number of young born, their colours, sex, and so on.

- *Field studies.* Data can be collected concerning the numbers of wild animals within a given area, for example, the woodpecker population in an area close to an industrialized or built-up area and one far removed. There are many studies that can be developed to determine the effects on animals of the various combinations of changes in the environment that humans have produced. Students can also build feeding stations and study bird populations or animal populations as they arise. An observation of animals in a dump is a worth-while project.
- *Study of the senses.* In studies based on sight, smell, and taste, only those things with which we may daily come into contact should be considered. Various studies can be done in which the behaviour of animals can be observed when they are exposed to various colours in their environment or to such strong odours as peppermint or onion. Ordinary food stuffs that are fed to laboratory animals can be coloured with vegetable dyes or altered with respect to taste by the addition of spices. Nothing should be added to the food that would be regarded as unacceptable to human senses.

Safety using plants

When flowers and bread mould are handled, care should be taken that pollen or spores are not excessively distributed throughout the classroom. Some students may be allergic to pollen or spores. As well, some plants in gardens, fields, forests, or at home may be poisonous, even though they are pretty. Poisonous plants may cause:

1. stomach and intestinal irritation;
2. poisoning of the system;
3. mouth and throat-lining irritation;
4. skin irritation.

The seriousness of plant poisoning will usually depend upon the amount swallowed. For some plants, even a small amount can be dangerous. The following are lists of common toxic plants. The number or numbers in parenthesis indicate the possible effects of swallowing them, as listed above.

House Plants

caladium (1,3)
castor bean (1,2)
dieffenbachia (1,3)
elephant's ear (1,3)
lantana (2)
mistletoe (1,2)
philodendron (1,3)
poinsettia (4)

A number of other poisonous plants, which are not native to Canada, are also grown indoors.

Vegetable Garden

potato – new shoots (2)
rhubarb – leaf blade (2)

Flower Garden Plants

autumn crocus – meadow saffron (2)
Christmas rose (1, 4)
daffodil (1)
foxglove – leaves and seeds (2)
golden chain (2)
hyacinth (1)
iris – blue flag (1)
larkspur – delphinium (2)
lily-of-the-valley (2)
monkshood (2)
morning glory (2)
narcissus (1)
snowdrop (1)
sweet pea – in large amounts (2)

Ornamental Plants

daphne (1)
mountain laurel (2)
rhododendron (2)
wisteria (1)
yew (1)

Field Plants

buttercup (1)
death camas (2)
false hellebore (2)
poison hemlock (2)
poison ivy (4)
pokeweed – inkberry (1,2)
snow-on-the-mountain (4)
thorn apple – jimson weed (2)

Trees and Shrubs

black locust (1,2)
box (1,2)
cherry – twigs, leaves, and bark (2)
elderberry – black elder (2)
horse chestnut (1,2)
privet (1)

Marsh Plants

cowslip – marsh marigold (1)
skunk cabbage (1,3)
water hemlock – cowbane (2)

Forest Plants

baneberry (1,2)
bloodroot (1,2)
fly agaric mushroom (2)
deadly amanita – deadly (2)
jack-in-the-pulpit (1,3)
May apple (1)
moonseed (2)
poison ivy (4)
poison oak (4)

Students should observe the following points about poisonous plants:

- Learn about the plants in your area that could cause harm.
- Learn to recognize the most common poisonous plants, such as poison ivy.
- Do not eat wild plants, including mushrooms.
- Do not eat any unknown plant, nor suck plant nectar.
- Do not play with plants or handle them excessively.
- Do not brew home-made medicines from plants.
- Keep plant seeds, bulbs, and fruit well away from small children.

If a student chews on or swallows part of a plant that is suspected of being poisonous, induce the student to vomit. Seek medical help; even simple skin irritation may deserve medical attention. A sample of the suspected plant may aid in the determination of needed treatment. In general, it is wise to leave plants in their natural state alone.



